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**EVALUATION AND LOADING
OF NEW EXPLOSIVE FORMULATIONS (U)**

J. T. Hamrick

L. C. Rose

Aerospace Research Corporation

TECHNICAL REPORT AFATL-TR-68-90

AUGUST 1968

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FOREWORD

(U) This report was prepared by Aerospace Research Corporation on Air Force Contract F08635-68-C-0030. The cratering evaluation and filling of the BLU-31 bombs was administered under the direction of the Advanced Technology Branch, Weapons Division, Air Force Armament Laboratory, Eglin Air Force Base, Florida. Capt. J. Trossbach was project scientist for the Armament Laboratory. The cardboard cylinders were furnished by Picatinny Arsenal and the tritonal was furnished by the Naval Weapons Station. The explosive evaluations by Lawrence Radiation Laboratory, the Naval Ordnance Laboratory, and the Naval Ordnance Test Station were made at the request of the Advanced Technology Branch with samples furnished without charge by Aerospace Research Corporation. Mixing, loading, test preparations, and testing of explosives at Aerospace Research Corporation were performed under the direction of Leslie C. Rose. The inclusive dates of the research reported are March 1965 to August 1968.

(U) Except as noted thermal evaluations, cycling tests, and shelf life evaluations were made by Aerospace Research Corporation. Thermal Stability tests performed by the U. S. Naval Ordnance Test Station were provided in a confidential memorandum which is included in Appendix I. Susan impact sensitivity test results were provided in confidential correspondence from the U. S. Naval Weapons Laboratory and are included in Appendix VI.

(C) The polyether urethane, nitramine formulations with and without aluminum are covered by patent. The patent (application serial number 659313) has been allowed but not issued due to a secrecy order issued by the Commissioner of Patents. Specific exclusion of any claim by the U. S. Government to patent rights to the explosive was made in Air Force Contract F08635-68-C-0030.

(U) Information in this report is embargoed under the Department of State International Traffic In Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Governments subject to approval of the Air Force Armament Laboratory (ATWT), Eglin AFB, Florida 32542, or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.

(U) This technical report has been reviewed and is approved.

Charles Petrides
for George P. Brenner, Colonel, USAF
Chief, Weapons Division

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CONFIDENTIAL ABSTRACT

(C) An evaluation has been made of AeReCo explosives 459-23 and 475. The explosives withstand 350°F for at least one hour and 300°F for eight hours. Their storability qualities are excellent and they are not affected by moisture at any climatic temperature. In cratering tests the AeReCo 459-23 equalled tritonal. Batch type loading techniques were evaluated by loading BLU-31 bombs.

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SECTION I

INTRODUCTION

(C) The new explosive formulations for which mixing, loading, and test results are provided herein show promise as candidates for filling bombs, land mines, and other armaments which will be subjected to high impact after being launched from high speed aircraft or to aerodynamic heating when externally mounted on supersonic aircraft or missiles. As a result, BLU-31 bomb cases were filled with both aluminized and nonaluminized formulations for subsequent sled testing by the U. S. Air Force. Preliminary to sled testing, Susan Impact tests were made by the U. S. Navy at Dahlgren, Virginia and the results are included in this report.

(C) The explosives for which the results of exploratory development work are presented utilize a polyether urethane rubber binder-fuel in combination with cyclotrimethylene trinitramine (hereafter referred to as RDX) and, optionally, aluminum powder. Most of the work to date has been directed toward evaluation of the explosives rather than manufacture. The results of thermal evaluations at several different laboratories as well as at Aerospace Research Corporation, cratering capability tests at the Aerospace Research Corporation high explosive test site, and hazard classification tests are presented herein. In addition, information which is preliminary in nature on mixing and loading of BLU-31 bomb cases is included. Stowage in 300 to 350°F environments, good physical characteristics, good cratering capability, and castability which have been demonstrated are discussed.

(C) The two formulations chosen for evaluation have been designated as AeReCo 475 and AeReCo 459-23. AeReCo 475 contains 25 percent binder and 75 percent RDX. AeReCo 459-23 contains 18 percent binder, 59 percent RDX, and 23 percent aluminum powder.

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SECTION II

SELECTION OF INGREDIENTS

(C) Of the ingredients used in the explosive, the binder is the one that sets it apart from other explosives. The binder possesses the right combination of properties to allow mixing and curing with nitramines and aluminum and after curing to have excellent physical characteristics over a wide range of environmental conditions. RDX alone or with aluminum powder is mixed with the binder to form a viscous slurry-like mixture which is then cured to the solid state. The binder is a polyether urethane and is derived from a combination of ether glycols and toluene diisocyanate with diols and polyols or polyols alone as cross linking agents. The binder in combination with aluminum and the nitramines are covered by a patent (Serial No. 659313) for which notice of allowance has been received, but which is being withheld from issue due to a secrecy order issued by the Commissioner of Patents. Ingredients for preparing the polyether prepolymer are not limited by the patent to those indicated herein. Ingredient selection factors are considered in the following subsections.

(C) Binder Selection - Both polyester and polyether urethanes were evaluated for this application. It was found that all types of polyester urethanes disintegrate when exposed to 95 percent relative humidity and 160°F for prolonged periods whereas the polyether urethanes do not. Exposure of the polyether urethane composites to 95 percent relative humidity and 160°F for six months resulted in no visible change in the shape or physical characteristics. The binder alone withstood 350°F for ten hours without significant degradation. The specimen was slightly less resilient but showed no tendency toward slumping or stickiness. Flexibility is retained at -65°F. The binder has been designated AeReCo 400. For RDX or RDX-aluminum mixtures, the ciphers are replaced by the percent of RDX and a dash number after the percent RDX is followed by the percent of aluminum powder when it is present.

(C) Aluminum Additive - The amount of aluminum that can be added to RDX is, percentage-wise, considerably larger than the amount that can be added to TNT while still increasing the effective explosive capability. It is indicated by results shown in reference 1 that the reaction of aluminum with oxygen in the primary explosive produces Al_2O in the gaseous state and that Al_2O_3 which is the normal oxide of aluminum does not exist in the gaseous state. Further, it is indicated that the gaseous phase of the oxide Al_2O does not exist below approximately 3500°K. Therefore, the heat of explosion of the primary explosive usually determines the percentage of aluminum which will produce optimum explosive power rather than the amount of oxygen available. It is further pointed out by Cook that the brisance of the explosive is considerably degraded by the use of aluminum but that the explosive power is significantly increased, thereby allowing a sizable increase in demolition capabilities by the addition of aluminum. With the decrease in brisance it does not follow that there will be an accompanying decrease in impact sensitivity of the explosive mixture. The particle size of aluminum to be used most effectively in this application has not been determined but there is some indication that particle size below 35-mesh screen size will not produce any additional effectiveness. This is a factor that will have to be determined together with the optimum particle size of RDX. For high temperature explosives it is probable that determination of

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the maximum amount of aluminum that can be used effectively will be well worth investigating both from a cost reduction and impact sensitivity standpoint. Further, it may be desirable in the future to evaluate perchlorate salts as an additive because of their high heat evolution upon their reaction with metals. Perchlorates, however, do not have the moisture resistance that may be required.

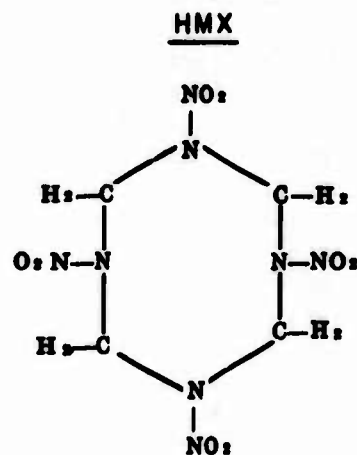
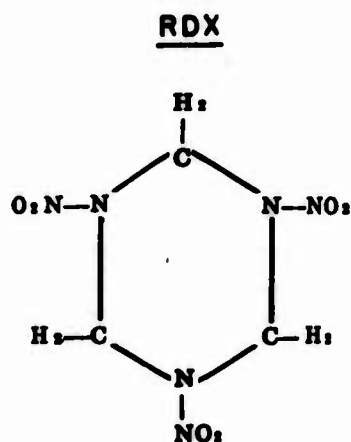
(U) Oxidizer Selection - A comparison of chemical and physical properties of HMX and RDX is shown on the chart (Table I) furnished by Holston Arsenal. Note that at 150°C (302°F) there is gas evolution from HMX although it is not as great as that for RDX. Therefore, for any application where there is continuous exposure to 300°F, gas will be evolved with both. The effect of this gas evolution and the length of time it can be tolerated can be determined only by laboratory testing of the end device. It should also be noted that with HMX there is a change in crystal density with change in temperature. The crystal density of HMX decreases with increasing temperature which means that the volume taken up by the crystals will increase. In going from beta crystals to alpha crystals at 115°C, there is approximately a four percent volume increase which takes place within the temperature range required for this application. There are no data available to show that the crystal phase change has given trouble in the past. However, past applications were for temperatures below 115°C and it is significant to note that ammonium nitrate which has a similar volume increase in going from room temperature to -65°F, has resulted in significant propellant grain growth in starter cartridges and extrusion of the propellant out of the cartridge case as a result of temperature cycling. RDX is not subject to this crystal phase change and may be more trouble free. Therefore, even though the detonation velocity of the HMX is a slightly higher than that for RDX as are the decomposition and explosion temperatures this crystal phase change may cause it to be less desirable in some applications. One advantage of the proposed system is that HMX can be substituted for RDX in applications where HMX may prove more suitable. All evaluations were made with type B, class A RDX. Type B RDX which is made by the Acetic Anhydride Process contains five to fifteen percent HMX. Therefore, compatibility of HMX with the other ingredients used in the formulation is assured to a large degree.

(C) Mixing Procedure - To prepare the urethane prepolymer, mix under a nitrogen atmosphere 46 parts of 2000 molecular weight polypropylene glycol and 31 parts of 3000 molecular weight propylene oxide adduct of 1,2,6 hexanetriol. Hold at 150°F until both components are liquid. Add 18.4 parts of 2,4 tolylene diisocyanate and 4.6 parts of 2,6 tolylene diisocyanate by means of a dropping funnel. Continue heating until a reaction temperature of 212°F is reached. Hold this temperature until a viscosity of 5000 cp at 77°F is attained. To prepare AeReCo 475, place 23.85 parts of the urethane prepolymer in a mixing bowl held at 200°F. Add 75 parts of RDX and mix until homogeneous. Add 1.15 parts of molten trimethylolpropane and mix until the trimethylolpropane is well distributed but not more than approximately five minutes. Mix in a vacuum mixer or evacuate the mix prior to pouring. Cure at 200°F for approximately 15 hours. To prevent foaming, all ingredients used in making the explosive must be kept water free. To prepare AeReCo 459-23, place 17.17 parts of the prepolymer in a mixing bowl held at 200°F. Add 23 parts of finely atomized aluminum powder and 59 parts of RDX and mix until homogeneous. Add .83 parts of molten trimethylolpropane and mix until the trimethylolpropane is well distributed but not more than approximately 5 minutes. From this point the procedure is the same as that for AeReCo 475.

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TABLE I COMPARISON OF CHEMICAL AND PHYSICAL PROPERTIES

(RDX AND HMX)



Formula

Molecular Weight	222.13	296.17
Melting Point (°C)	204 (dec)	280 (dec)
Explosion Temp (5 sec)	260°C	327°C
Vacuum Thermal Stability (cc gas/gm in 48 hr)		
at 100°C	0.10	0.10
at 150°C	3.0	0.60
Confined "Cook Off" Temp (°C)	180	210
Crystal Density (gm/ml)	1.802	1.90 (Beta) 1.82 (Alpha) 1.76 (Gamma) 1.80 (Delta)
Heat of Combustion (kcal/mole)	501.82	667.41
(kcal/gm)	2.260	2.255
Heat of Formation (kcal/mole)	-14.71	-17.93
Heat of Detonation (calc)		
(H ₂ O gas) (cal/gm)	1228	1222
Heat of Explosion (calc)		
(H ₂ O liq) (cal/gm)	1362	1356
Detonation Velocity (m/sec)		
97% Voidless Density	8743	9124
Slope (m/cc/sec/gm)	3700	3700

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SECTION III

PHYSICAL CHARACTERISTICS

(C) The cured explosives are not brittle, even at low temperatures. They may be machined with the precaution of frequently removing shavings and are easily sawn. Remote cutting and machining has not been found necessary because of the poor burning characteristics in air.

(C) Density - The computed density of AeReCo 459-23 is 1.88 grams per cc. Density based on weight and physical measurement is 1.72 grams per cc. The computed density of AeReCo 475 is 1.65 grams per cc. The average density based on physical measurement is 1.5 grams per cc.

(C) Linear Coefficient of Expansion - Measurements were made after stabilization at -65°F and 180°F for AeReCo 459-23. Based on these measurements the average linear coefficient of expansion is $.33 \times 10^{-4}$. Determination of the expansion coefficient was not made for AeReCo 475.

(C) Physical Strength - Tensile tests have not been made with the explosive primarily because of erratic results obtained as a result of notch sensitivity with machined specimens. Shear strength testing with 24 percent AeReCo 400 binder and 76 percent ammonium perchlorate cast in an impregnated fibre tube showed an average shear strength of 1030 pounds per square inch for the explosive and the bond interface between the fibre tube and explosive. The perchlorate explosive is adequately physically similar to the RDX explosive to expect a similar strength for the AeReCo 475 and possibly a lesser value for the AeReCo 459-23.

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SECTION IV

THERMAL EVALUATION AND SHELF LIFE

(C) Ability of the explosive to stand up at +350°F for one hour without physical deterioration, reaction with surrounding medium, autoignition, or explosion was set as the goal in thermal stability evaluations. Shelf life expectancy is based on both storage at ambient conditions and temperature cycling results.

(C) Thermal Stability - The thermal stability evaluation was made with 3/8 inch cubes of material, center drilled with a sheathed 1/16 inch diameter thermocouple injected into the center of and supporting the cube. The oven in which the specimen was tested was controlled so that the wall temperatures remained at 350 ± 3°F throughout the test. The thermocouple in the specimen indicated that the center of the cube reached +350°F within six minutes after the wall of the oven reached +350°F. Samples of AeReCo 459-23 and 475 explosive were thus exposed to +350°F in air for one hour without slumping, melting or undergoing significant change in geometrical proportions. However, there was approximately a three percent weight loss which is attributed to loss of the RDX. The confined cook-off temperature of RDX is 180°C (356°F) as shown by the comparison of chemical and physical properties in Table I. "Cook-off" in ordnance terminology is generally used in reference to rounds left in a hot gun in case of jamming (ref. 2, page 28-24) and it is assumed that with RDX a high degree of confinement would be required at +356°F before an explosion would occur. Based on tests with propellants containing 65 percent RDX, cook-off in this manner would not result in detonation until an extremely high pressure, in excess of 500,000 psi, is reached. The types of armament, degree of confinement, etc., would determine the statistical chances of reaching a high pressure under conditions of +350°F and the hazard involved in the use of such armament can be determined only by environmental tests which simulate field use conditions. Independent and more definitive thermal stability tests for AeReCo 459-23 were performed by the U. S. Naval Ordnance Test Station at China Lake, California and the results are included in Appendix I of this report. Those tests confirm the ability of AeReCo 459-23 to withstand 350°F for at least one hour.

(C) Differential Thermal Analysis - Tests that were made at the Naval Ordnance Test Station, Appendix I, also included differential thermal analysis among others. Additional differential thermal analysis tests were performed by Lawrence Radiation Laboratory and are included in Appendix II. The results of these tests are adequately discussed in Appendices I and II and, therefore, are subjected to no further comment. Two binder specimens with different ether glycols were given vacuum stability tests at the U.S. Naval Ordnance Laboratory and the results are contained in a letter which has been included as Appendix III. Binder 400 A was used in all samples for which tests are reported in Appendices I and II.

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(C) Shelf Life - An eight pound specimen containing 63 percent RDX, thirty one percent binder, and remainder an inert ingredient has been exposed to the ambient environment under shelter, at Roanoke, Virginia for 42 months without any visible change. In addition to ambient exposure a specimen of AeReCo 459-23 5 inches by 5 inches by 2.8 inches was cycled from -65 to 180°F for 27 cycles without any visible change. The cycles consisted of 16 hours in a -65°F chamber followed by 8 hours in a 180°F chamber except for two weekends in which the specimen was kept at 180°F for 56 hours each, and one weekend in which it was kept at -65°F for 48 hours. The 2 inch cubes for which the test results are shown in Appendix III were cut from this specimen after the cycling tests were completed. The shelf life can be expected to greatly exceed five years.

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SECTION V

IMPACT SENSITIVITY AND HAZARD CLASSIFICATION

(C) Drop weight impact sensitivities were run on the Lawrence Radiation Laboratory machine using a 5 kilogram weight and type 12 tools with sandpaper. The results are shown in Appendix II. The AeReCo 459-23 is less than half as sensitive as HMX from a drop height standpoint and more sensitive than the AeReCo 475. Additional sensitivity tests were made with two inch cubes of explosive which were subjected to the impact of a number 8 blasting cap. The results of these tests are given in Appendix IV. No detonations occurred in these tests. As noted in Appendix IV, both AeReCo 459-23 and 475 are classified as Class B explosives by the Bureau of Explosives. Class B is not equivalent to Military Class II in that the impact criterion for Class B by current practice of the Bureau of Explosives is insensitivity to a number 8 blasting cap whereas the impact criterion for Class II by the military is insensitivity to 2 pentolite boosters 1 inch long by 2 inches diameter through seventy 0.01 inch cellulose acetate cards which delivers a much greater impact than a number 8 cap.

(C) The tests which were made to determine military classification are included in the summary sheet in Appendix IV. Card gap tests were not performed, but by comparison, it is estimated that approximately 140 cards 0.01 inch thick will be required to prevent detonation of the AeReCo explosives. From the results of the test and the known fact that in the card gap test the number of cards will exceed 70, the military classification of both explosives is Class 7.

(C) Susan impact sensitivity tests on AeReCo 475 and AeReCo 459-23 were conducted by the U. S. Naval Weapons Laboratory and the results are included herein as Appendix VI. Tests with desensitized tritonal were made and the results are also included. The results indicate that desensitized tritonal is less sensitive than the AeReCo explosives under the conditions to which the explosives were exposed. It is possible that the AeReCo explosives can be made less sensitive by using a finer than Class A RDX. However, the finer RDX could make processing more difficult. The physical strength of AeReCo explosives is much greater than that of tritonal, and therefore both of the types tested would offer greater resistance to crushing upon impact. Thus, a proportionately greater amount of heat should be generated within the specimen. Encasement of the explosive within a shield which together with the explosive is strong enough to withstand crushing may provide a significantly improved result. If this should be true a reduction in bomb case wall thickness might be possible for the AeReCo explosives over that now required for tritonal.

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SECTION VI

DETONATION ENERGY

(C) A measure of the detonation energy of both AeReCo 459-23 and AeReCo 475 were determined from cratering tests with thirty pound charges. The procedure used in reference 3 was followed as closely as possible in order to allow comparison with the results given therein for thirty pound charges. The experimental approach and experimental results for the cratering tests are presented in this section.

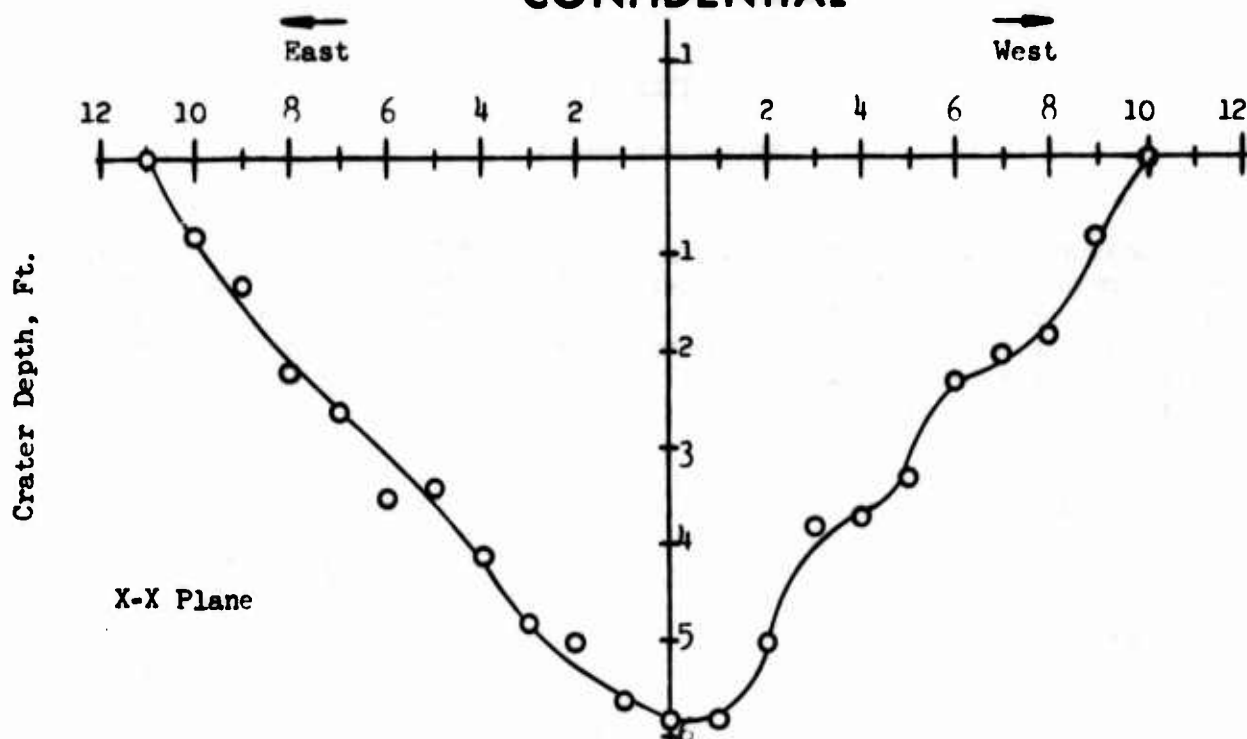
(C) Experimental Approach-Thirty pound explosive charges of AeReCo 459-23, AeReCo 475, and tritonal were cast in cardboard cylinders of 7 inches inside diameter by 1/4 inch thick walls. Four of each were detonated with their centers of gravity either 6 or 7 feet below ground surface in a 9 1/2 + 1/2 inch diameter hole. Each was covered with fill 2.5 feet above the charge C.G. More specific details are provided in Appendix V. Prior to testing and boring the holes the ground was leveled so as to provide a square plot of virgin soil approximately 20 feet on a side for each specimen. Soil samples were taken at 0, 3, and 6 feet and sealed in a glass jar for future analysis if desired. The soil varied from a soft to hard, deteriorated schist.

(C) Experimental Results-The results of the tests are given in figures 1 through 28 and Tables II through XIII. It can be seen from figures 1 through 12 that the cratering capabilities of AeReCo 459-23 and tritonal are similar and that both are much superior to AeReCo 475. That both aluminized explosives are superior in cratering capability to a nonaluminized explosive is in agreement with reference 1. The crater volumes and averages for each type explosive at each depth including results obtained for 30 pound charges of tritonal in reference 3 are as follows:

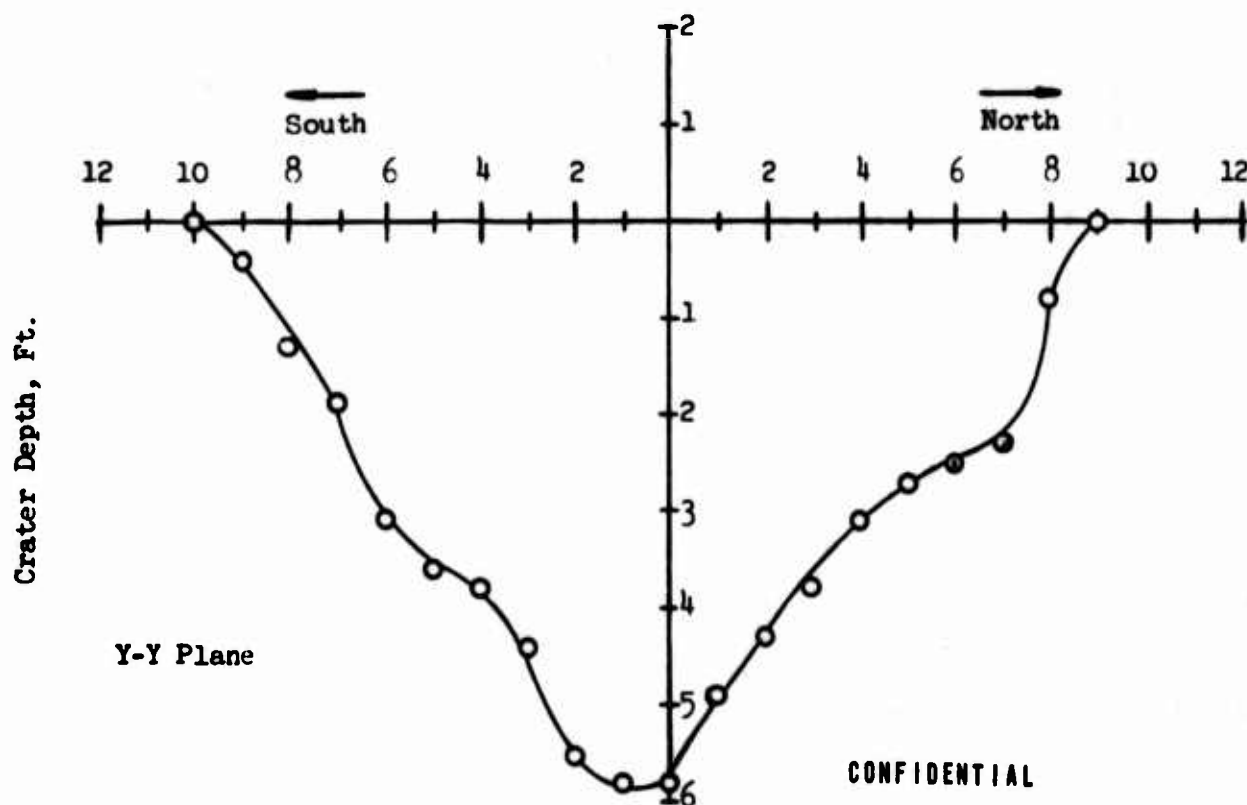
Sample No.	Depth Ft.	AeReCo 459-23 Vol. Cu. Ft.	AeReCo 475 Vol. Cu. Ft.	Tritonal Vol. Cu. Ft.	Tritonal From Ref. 3 Vol. Cu. Ft.
1	6	700	171	379	301
2	6	197	207	326	268
3	7	141	0	345	205
4	7	621	0	651	234

It is indicated from the results that the soil variation was a major factor. Large chunks of hard soil can be seen in figure 19 for sample 3 of AeReCo 459-23. The hardness of the soil may account for the quite low volume of 141 cubic feet. The reason for the larger hole volume for tritonal at the Aerospace Research Corporation site than at the Corps of Engineers site probably is also due to differences in the soil.

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Crater Radius, Ft.

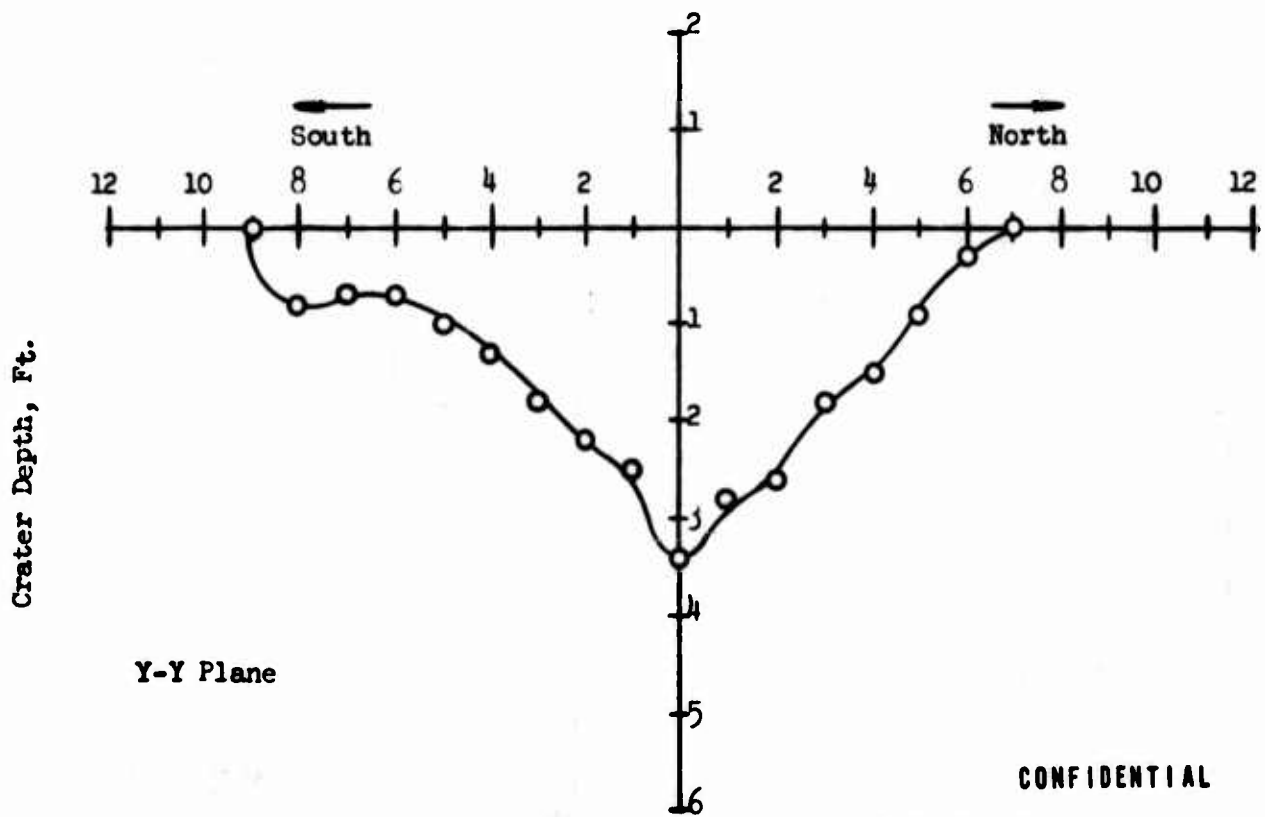
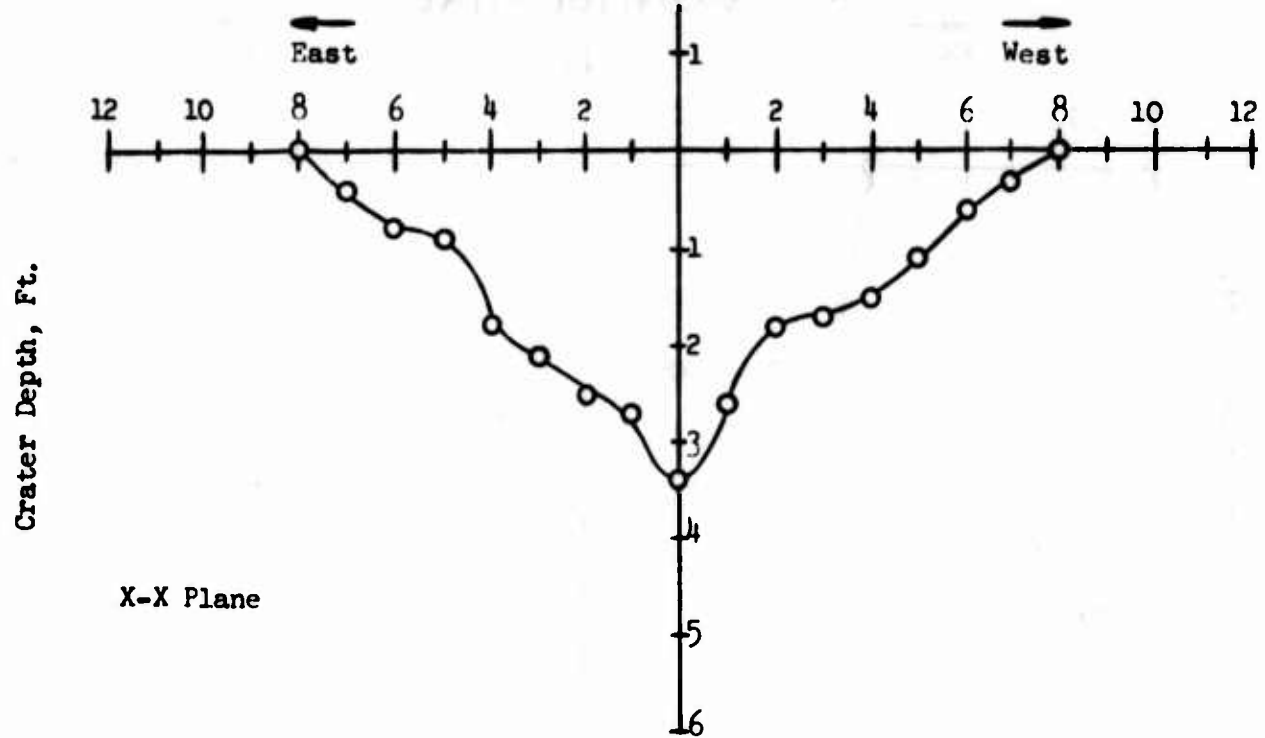


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Figure 1 - Crater Profile - Sample: AeReCo 459-23, 1.

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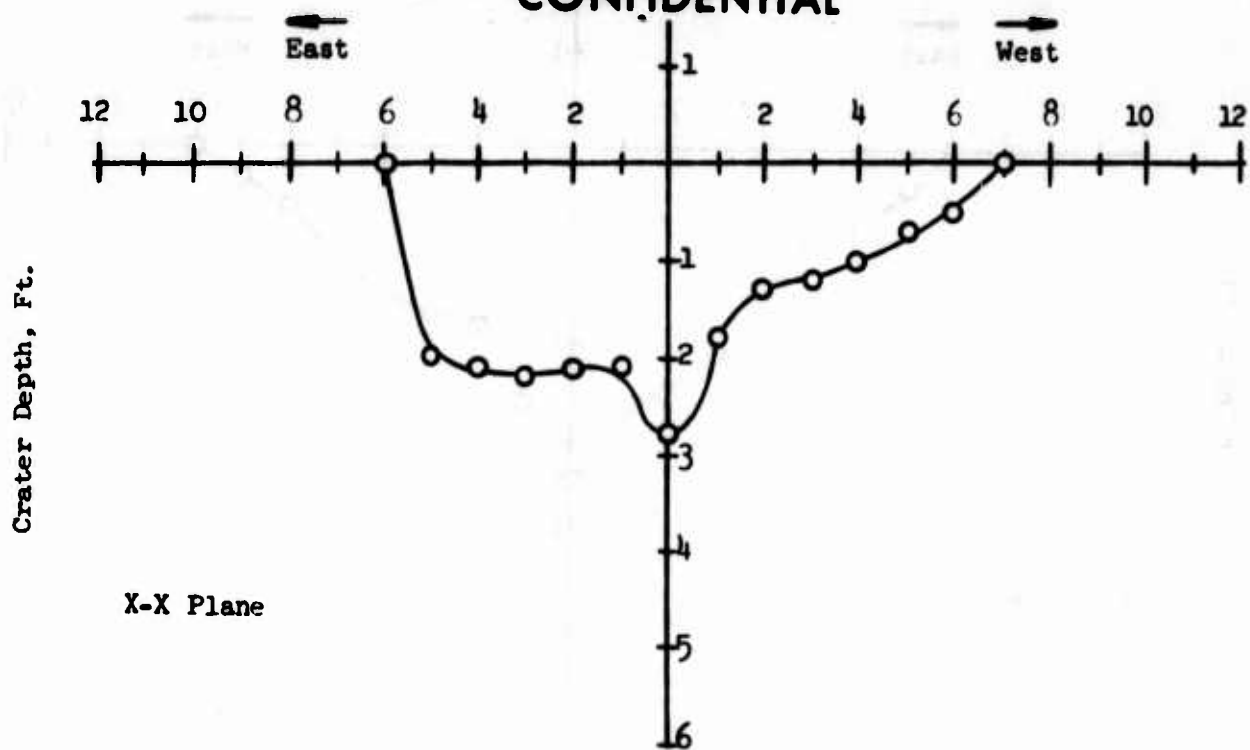


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Figure 2 - Crater Profile - Sample: AeReCo 459-23, 2.

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Crater Radius, Ft.

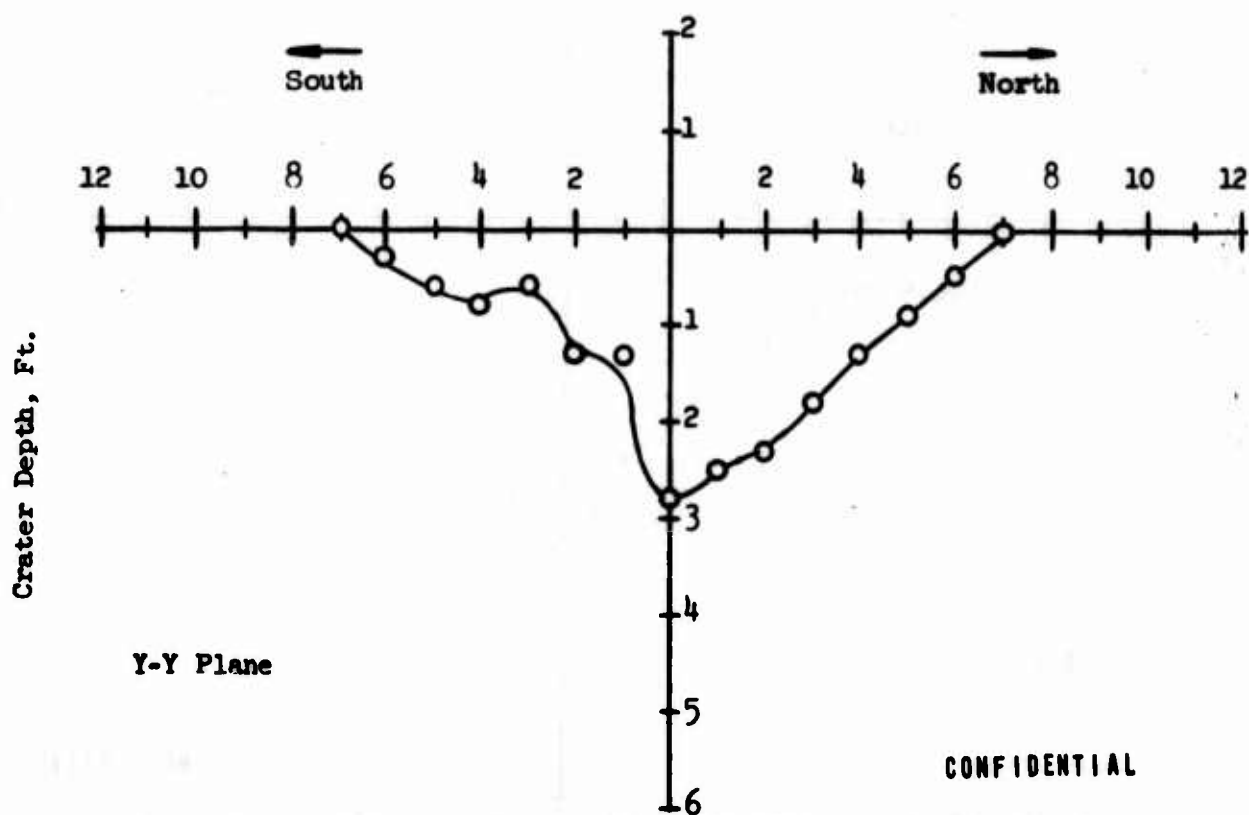


Figure 3 - Crater Profile - Sample: AeReCo 459-23, 3.

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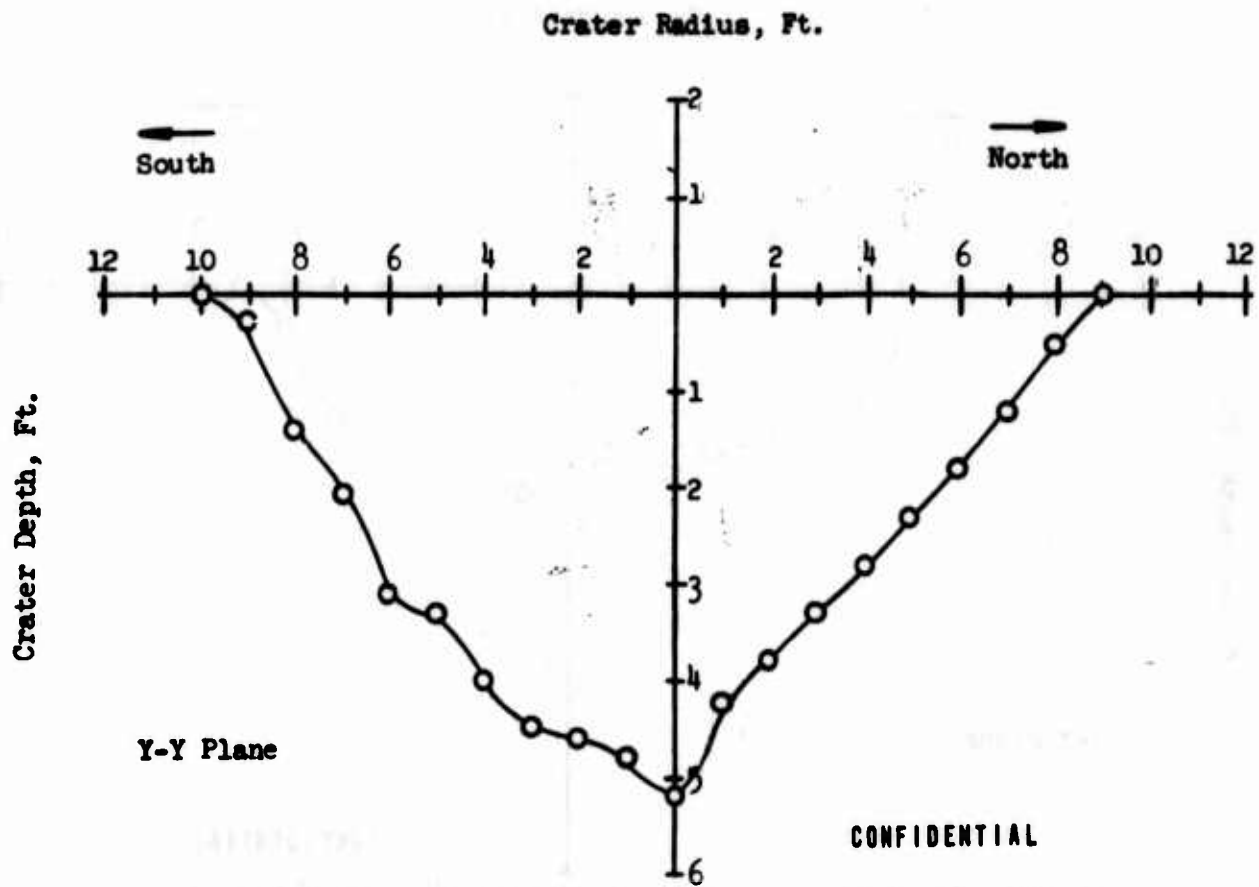
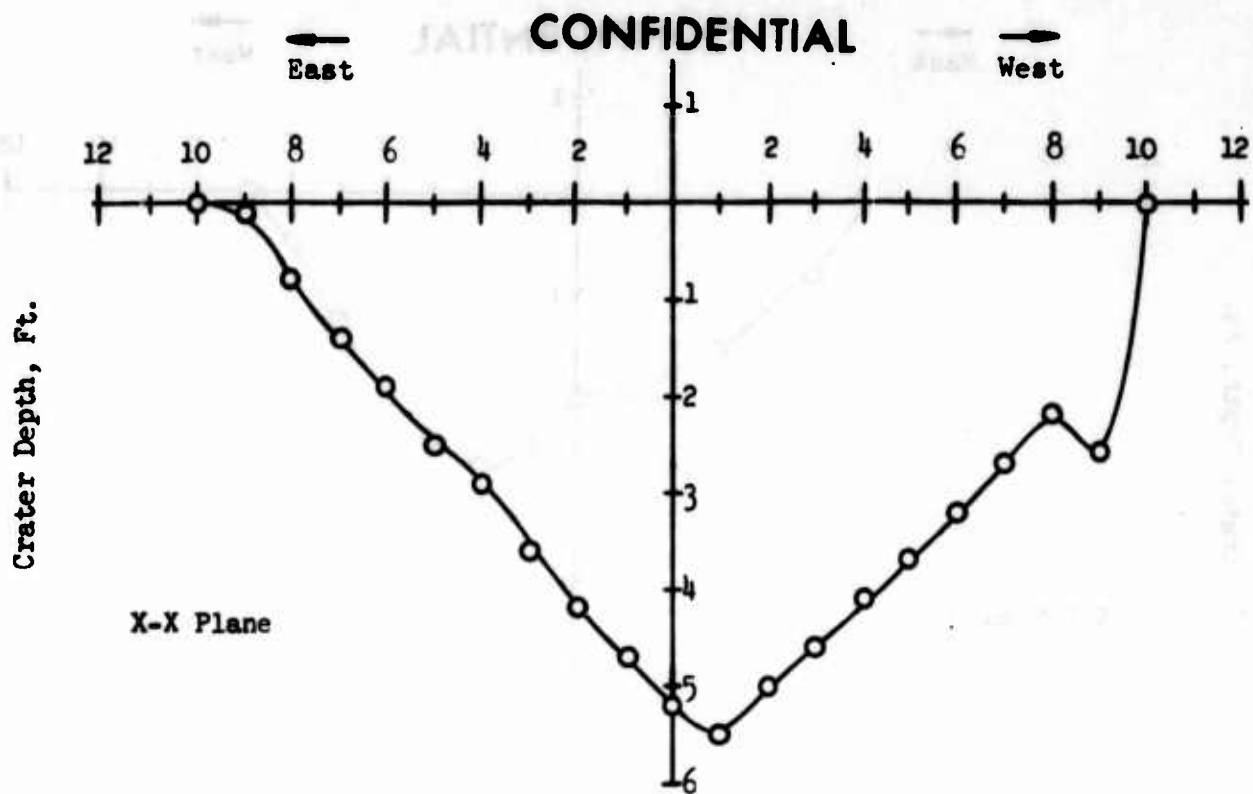


Figure 4 - Crater Profile - Sample: AeReCo 459-23, 4.

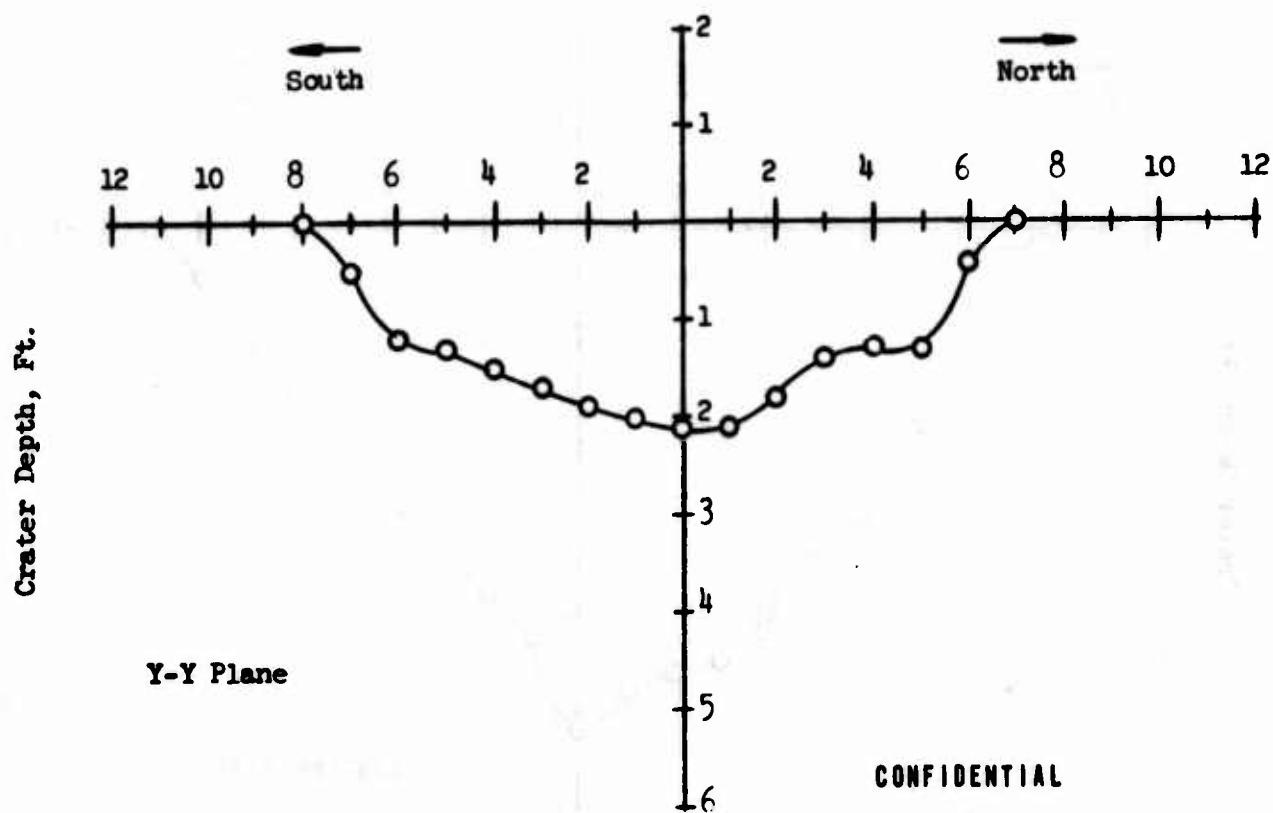
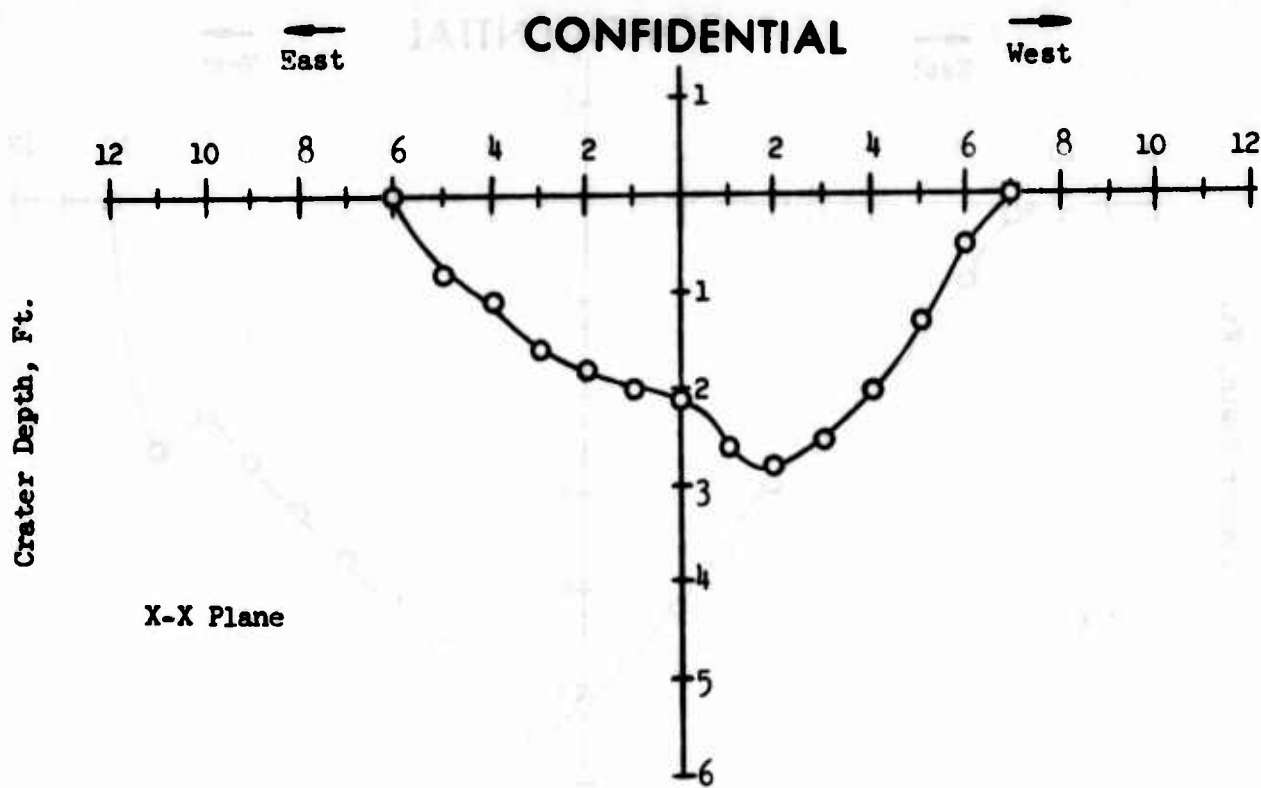


Figure 5 - Crater Profile - Sample: AeReCo 475, 1.

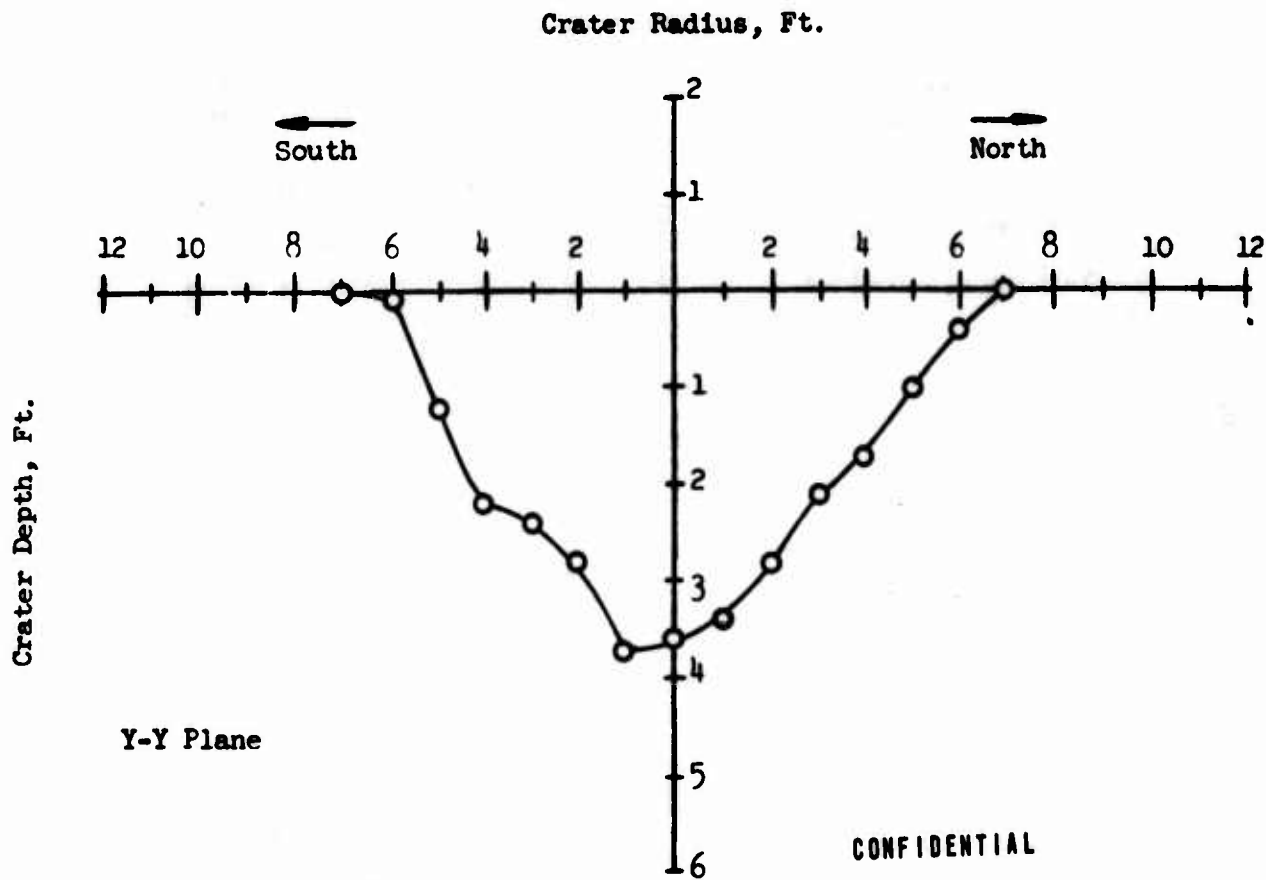
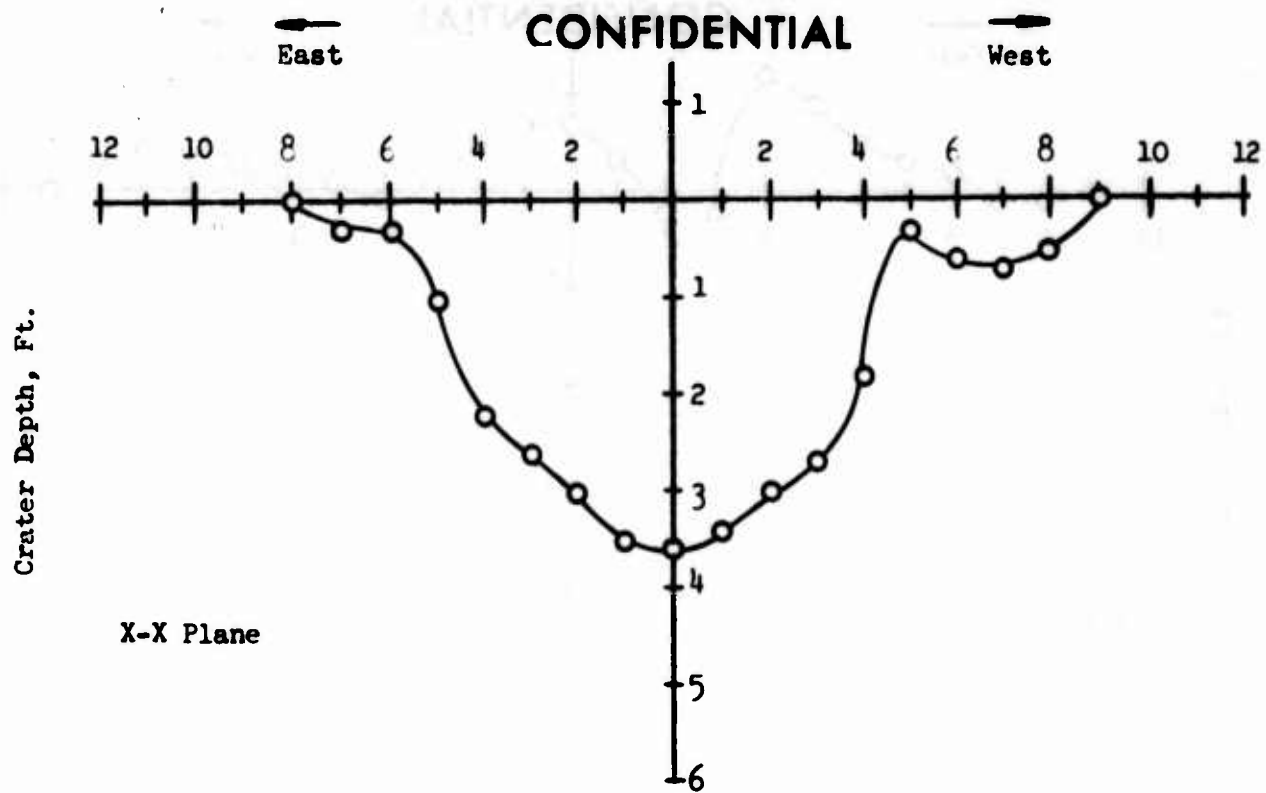


Figure 6 - Crater Profile - Sample: AeReCo 475, 2.

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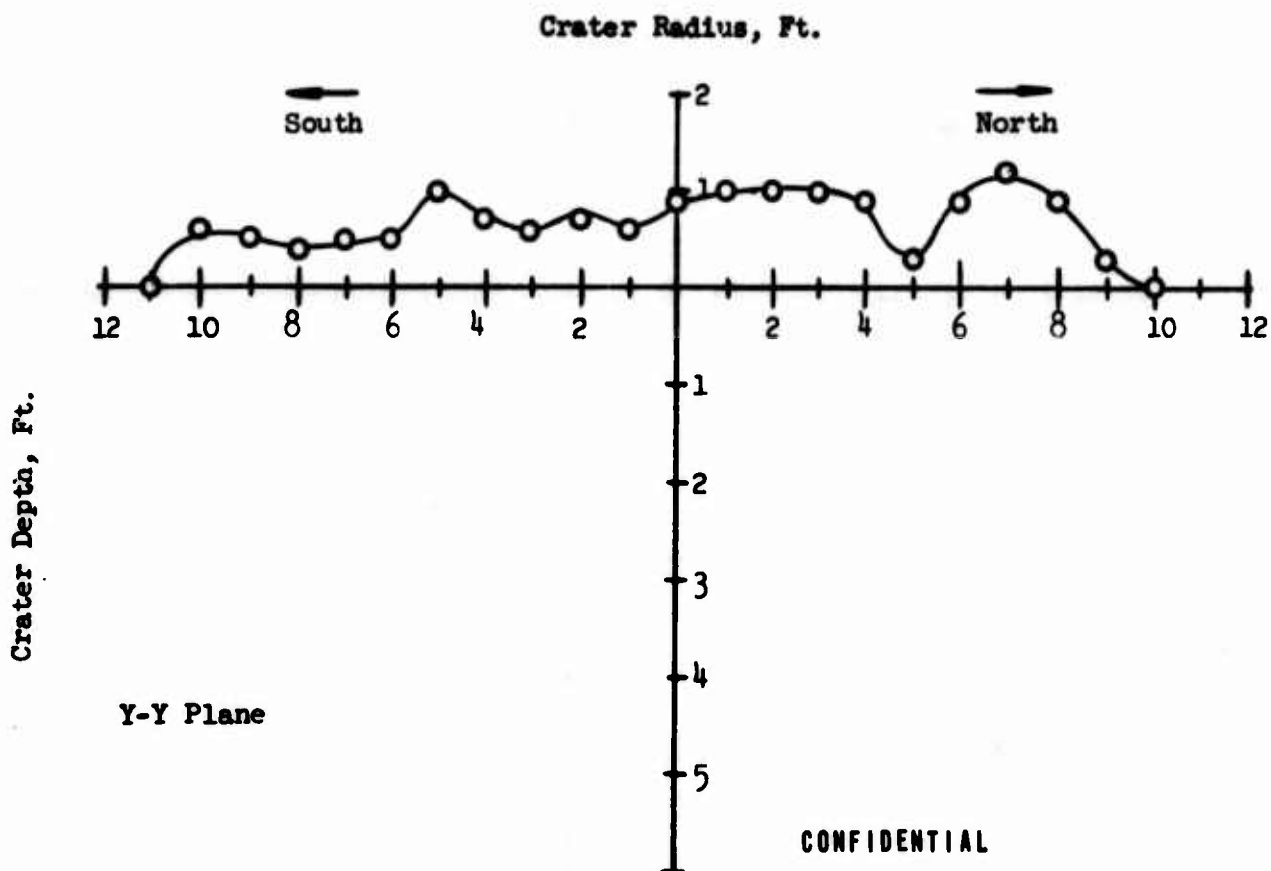
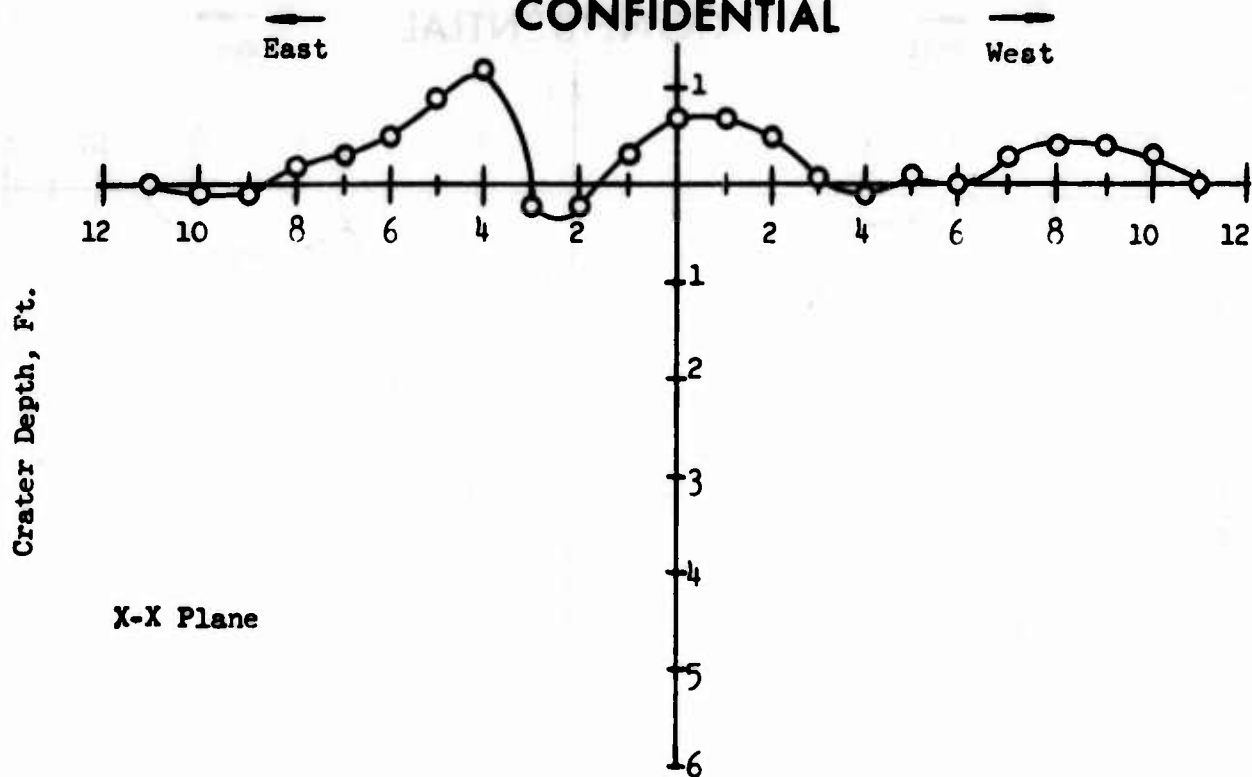
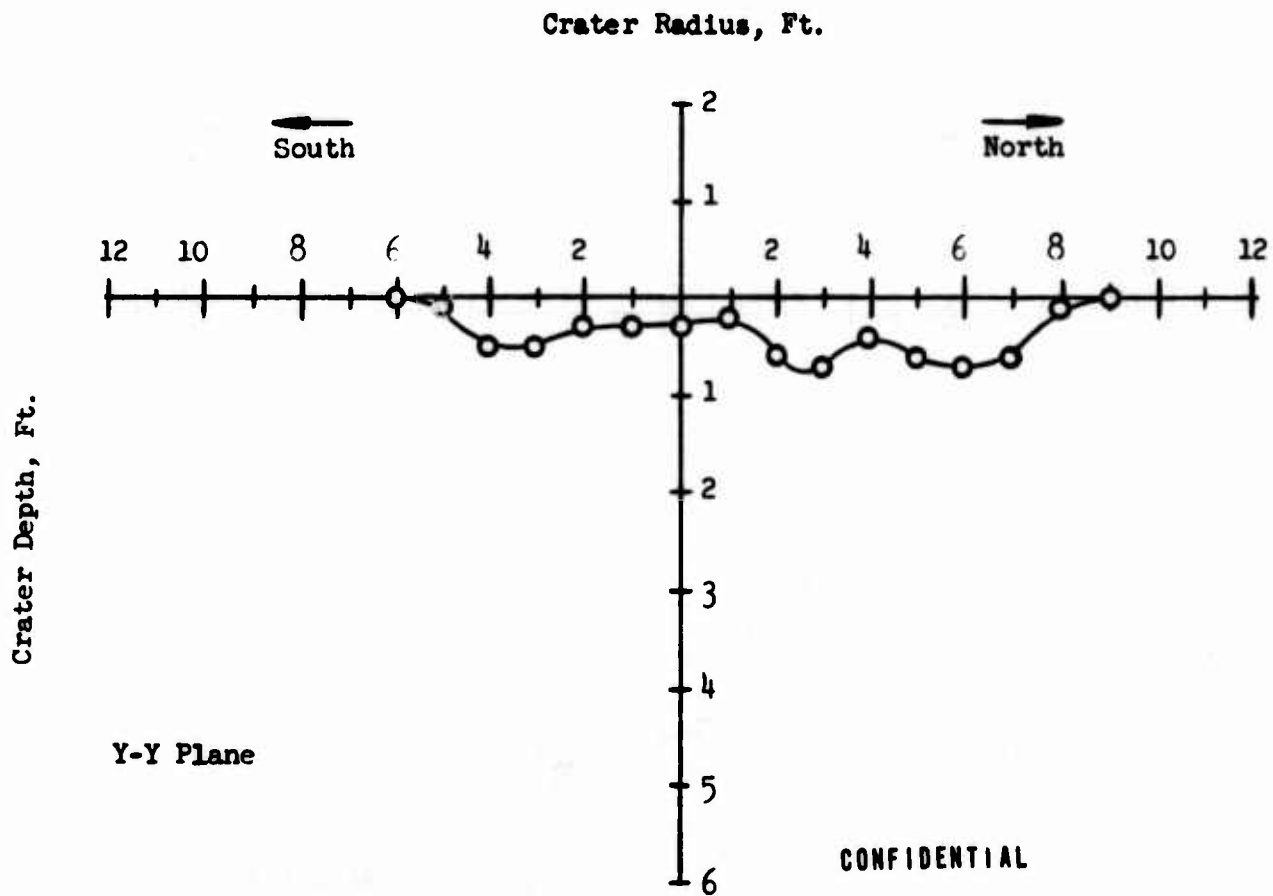
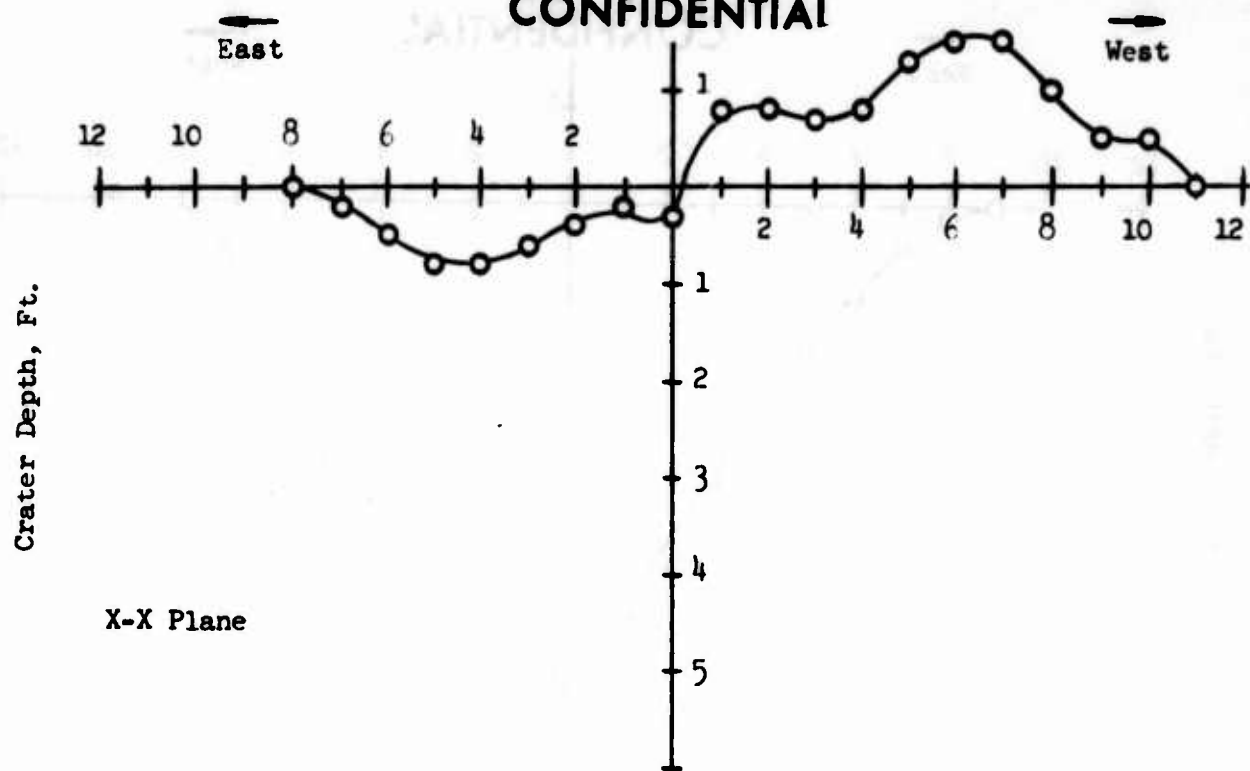


Figure 7 - Crater Profile - Sample: AeReCo 475, 3.

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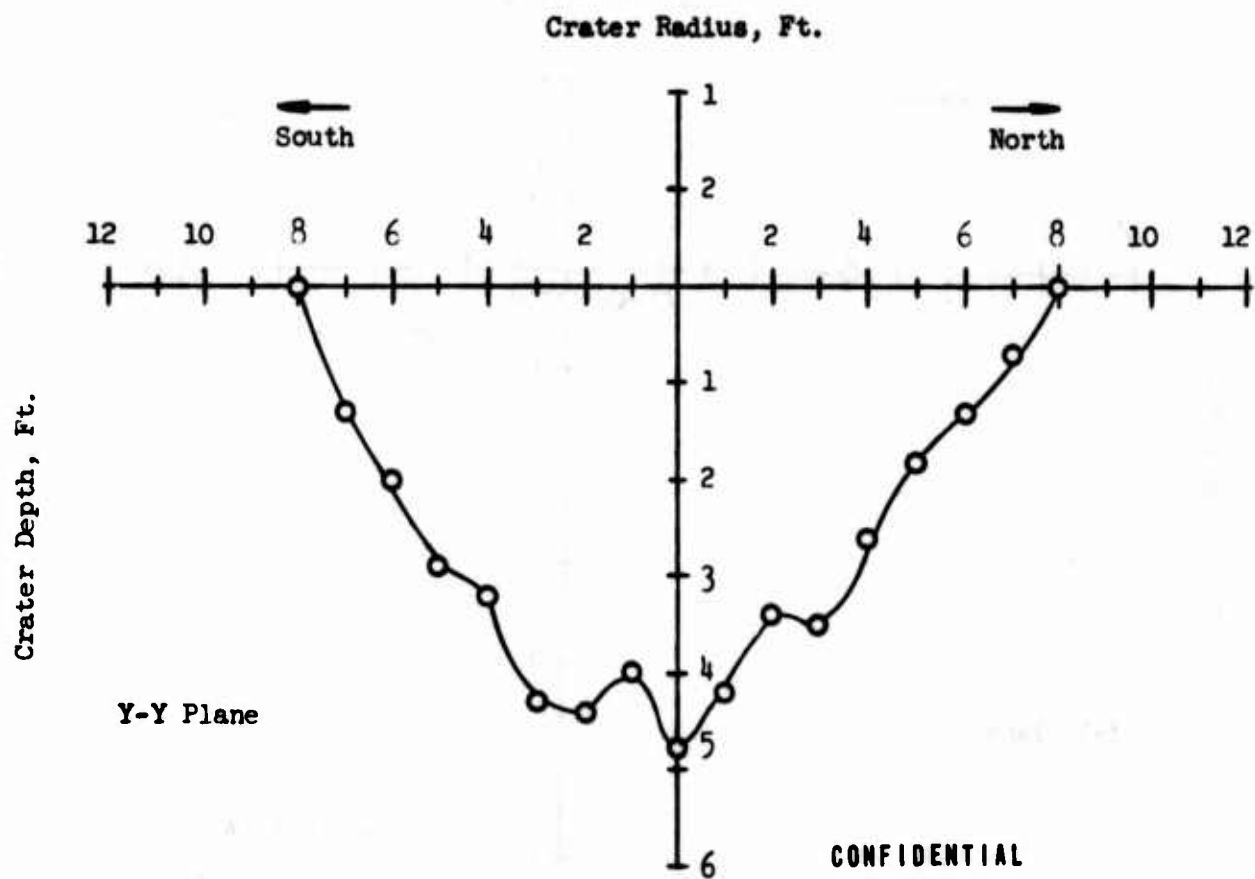
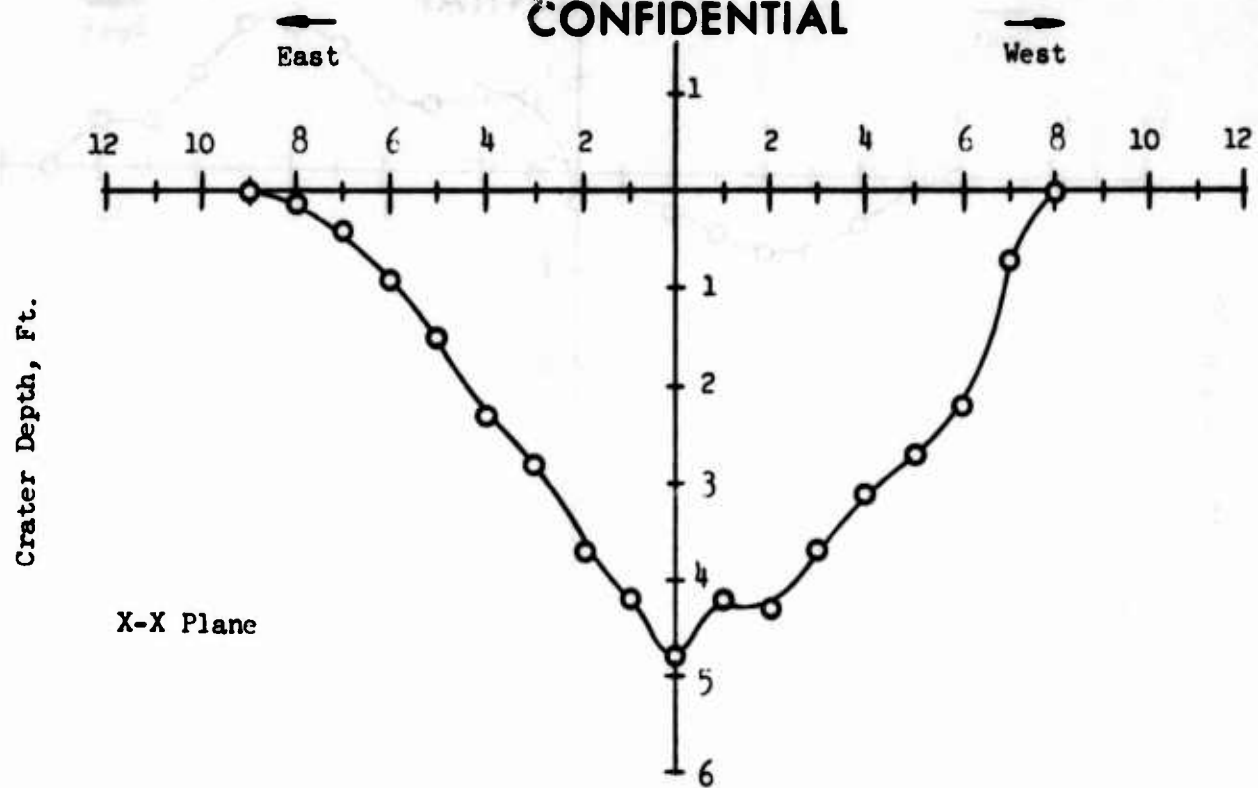


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Figure 8 - Crater Profile - Sample: AeReCo 475, 4.

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Figure 9 - Crater Profile - Sample: Tritonal, 1.

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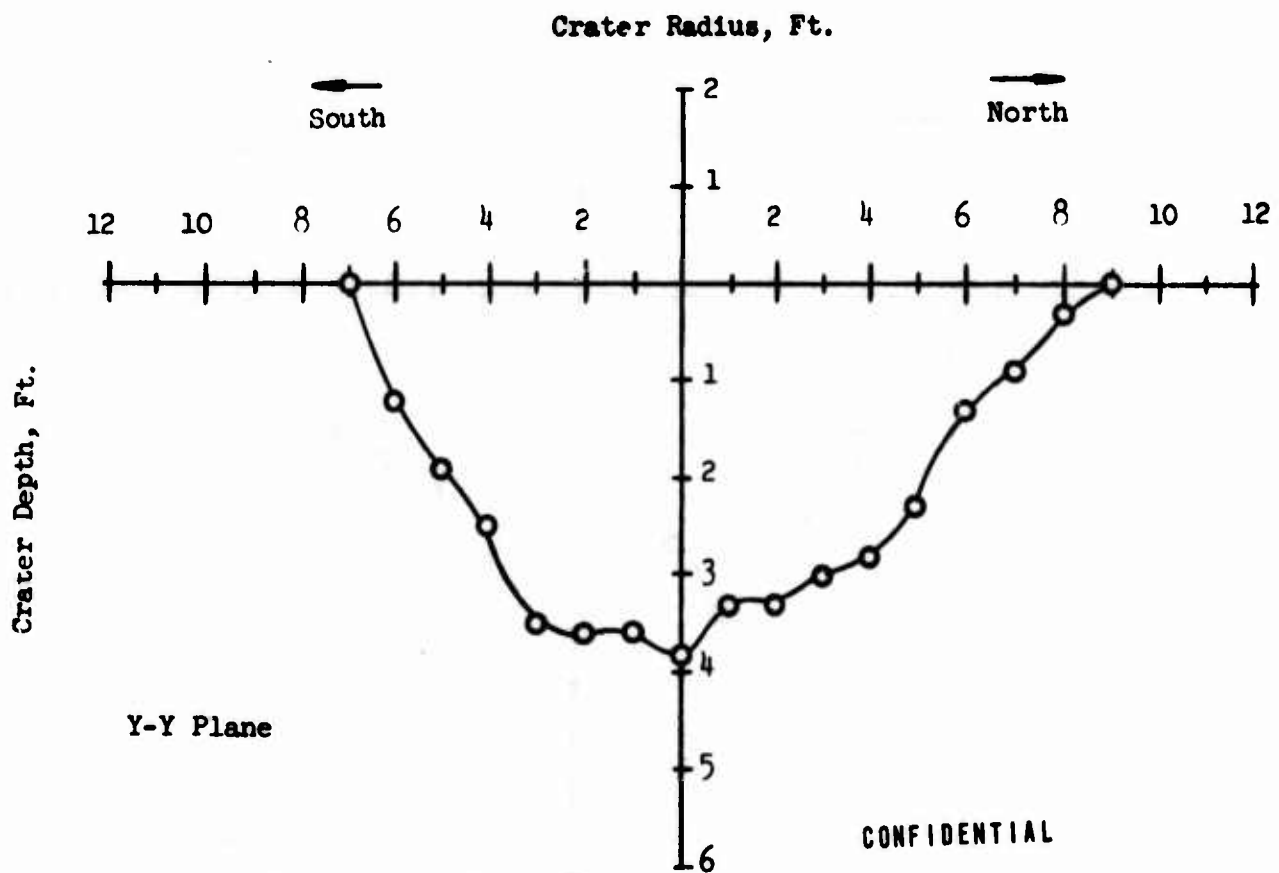
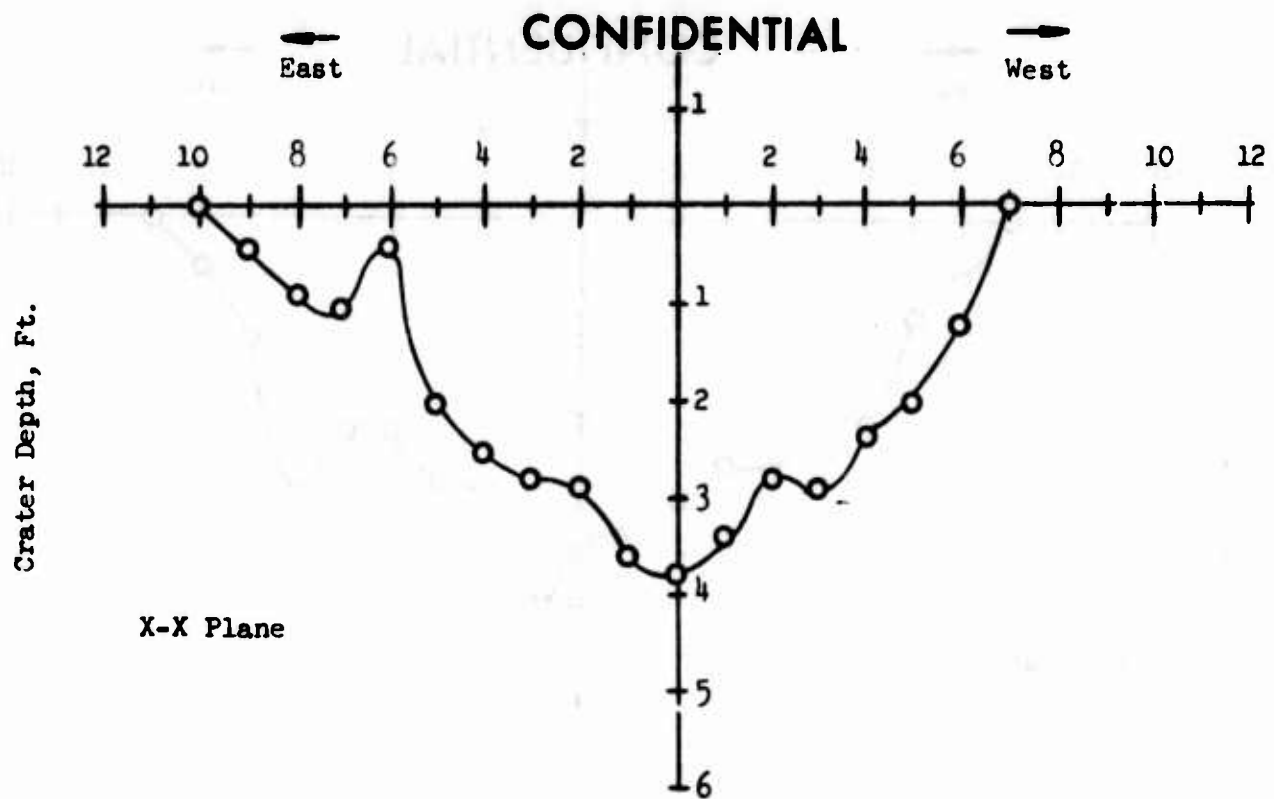


Figure 10 - Crater Profile - Sample: Tritonal, 2.

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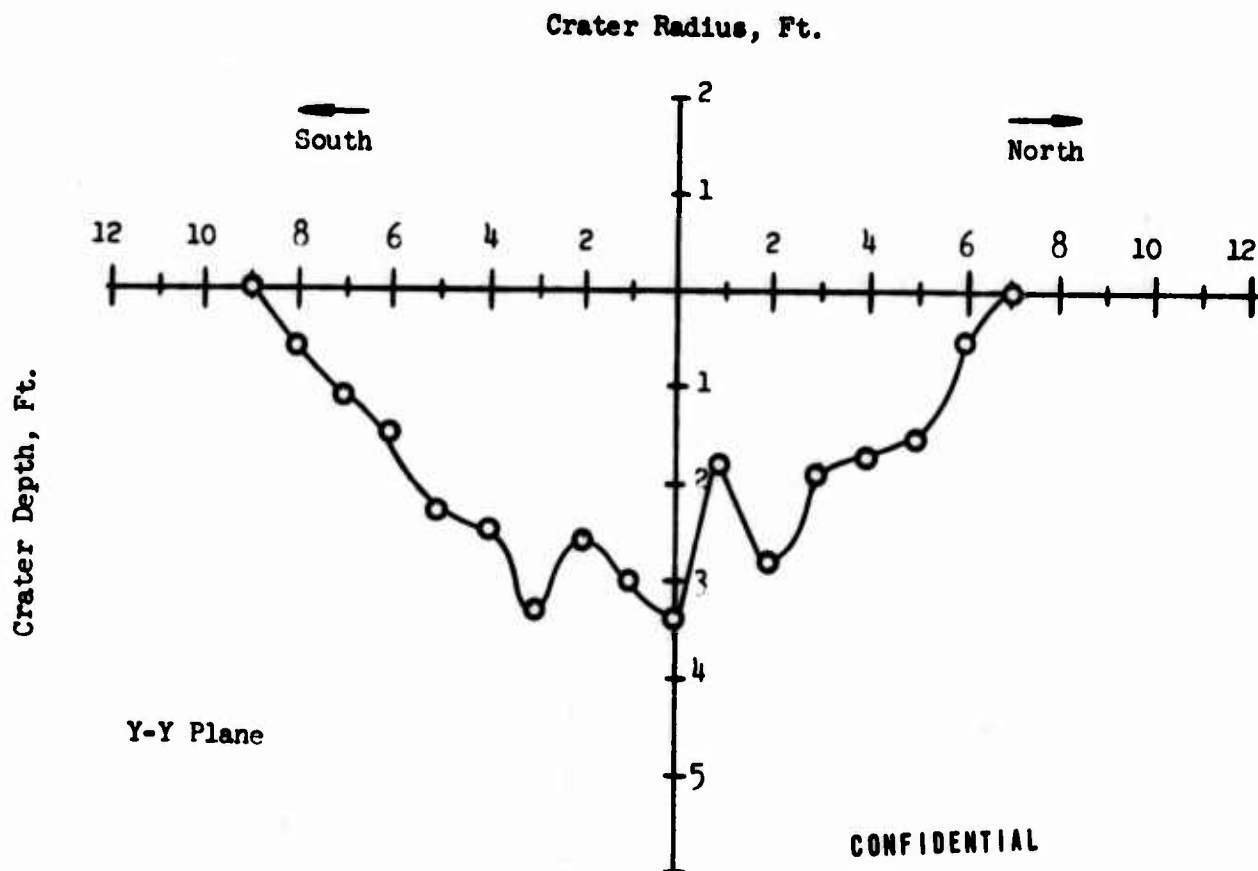
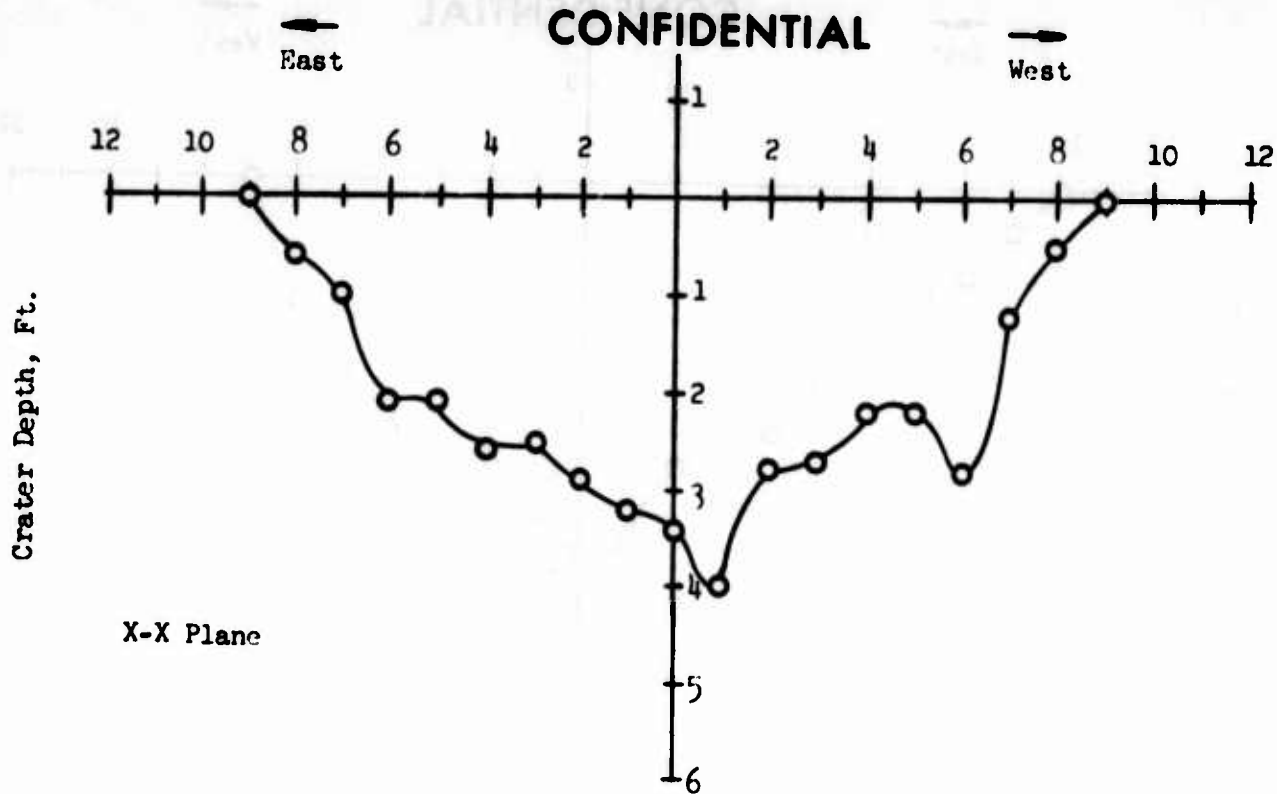


Figure 11 - Crater Profile - Sample: Tritonal, 3.

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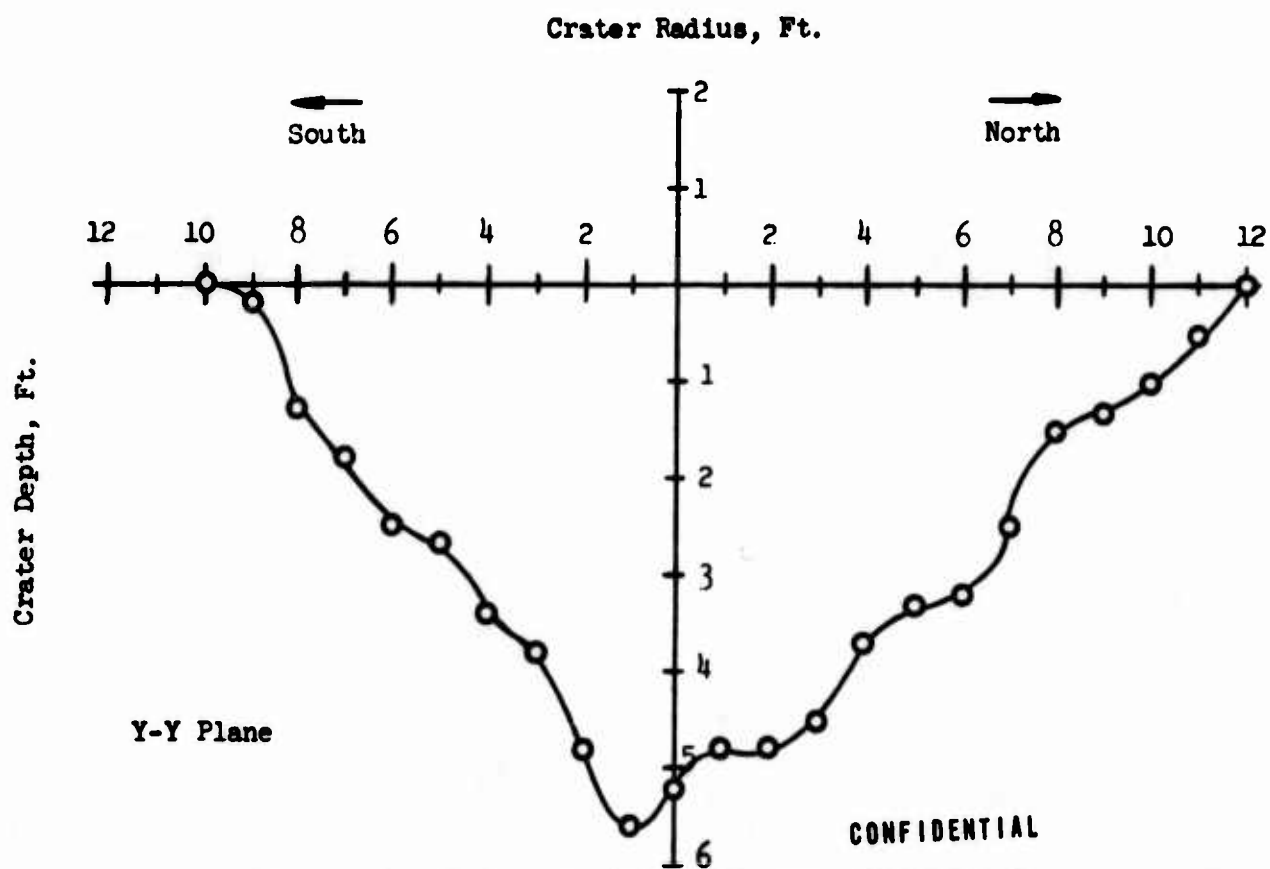
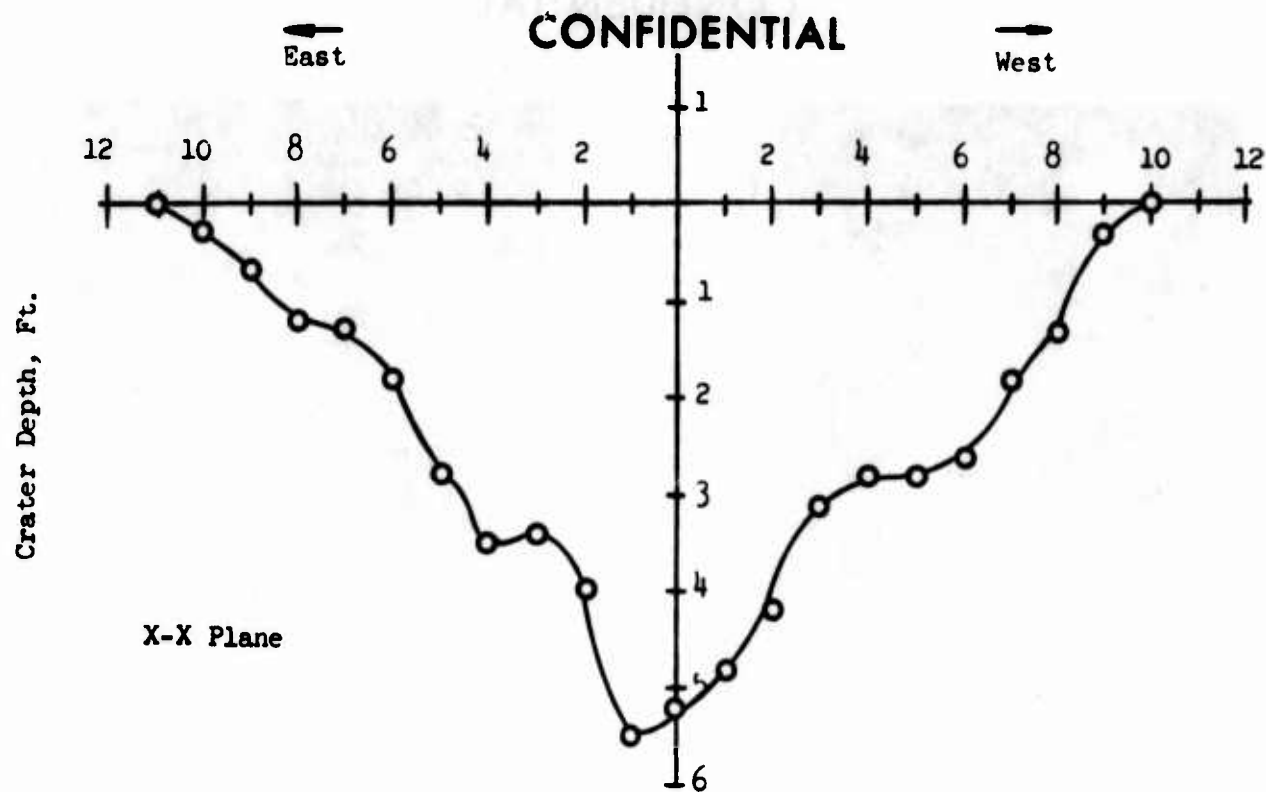
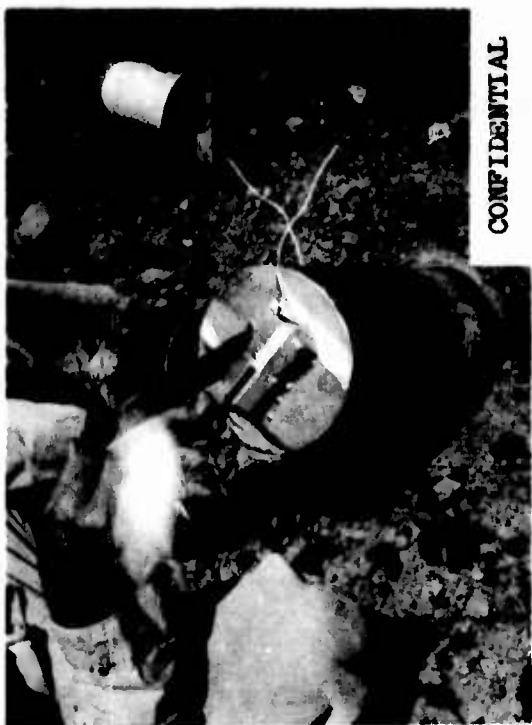


Figure 12 - Crater Profile - Sample: Tritonal, 4.

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Figure 14 - Test Sample with Pentolite and Blasting Caps



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Figure 16 - View of AeReCo 475, Sample 1 and Test Hole



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Figure 13 - Photograph of Test Area



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Figure 15 - View of Tritonal Sample 1 and Test Hole

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Figure 18 - Blast Crater, Sample 2,
AeReCo 459-23

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Figure 20 - Blast Crater, Sample 4,
AeReCo 459-23

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Figure 17 - Blast Crater, Sample 1,
AeReCo 459-23

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Figure 19 - Blast Crater, Sample 3,
AeReCo 459-23

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Figure 22 - Blast Crater, Sample 2,
AeReCo 475



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Figure 24 - Blast Crater, Sample 4,
AeReCo 475



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Figure 21 - Blast Crater, Sample 1,
AeReCo 475



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Figure 23 - Blast Crater, Sample 3,
AeReCo 475



Figure 26 - Blast Crater, Sample 2,
Tritonal



Figure 28 - Blast Crater, Sample 4,
Tritonal



Figure 25 - Blast Crater, Sample 1,
Tritonal



Figure 27 - Blast Crater, Sample 3,
Tritonal

TABLE II. CRATERING TEST SAMPLE NUMBER 1, AeReCo 459-23

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 1 Test Sequence No. 3 Date 6-29-68
Explosive Type AeReCo 459-23 Batch No. 17 Charge Wt., lbs. 30 Charge Volume, in³ 593
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 92 R.H.% 40
Hole Diameter, in. 9 3/4 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5
35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 21 ft. Crater Diameter, Y-Y Plane 19 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	1	2	2	3	3	4	4	5	5	5	5	5	3	3	3	2	2	1	0	0
Depth: in.	8.5	3	2	7	6	5	1	9.5	0	7	9	9	0	9	8	3	3	0	9	8.5	0

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	1	1	3	3	3	4	5	5	5	4	4	3	3	2	2	2	0	0	0
Depth: in.	0	5	3.5	11	1	6.5	10	5	6	8.5	9	11	3.5	8.5	1	8	5.5	4	10	0	0

Remarks: _____

TABLE III. CRATERING TEST SAMPLE NUMBER 2, AeReCo 459-23

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 2 Test Sequence No. 9 Date 7-1-68
Explosive Type AeReCo 459-23 Batch No. 1 Charge Wt., lbs. 30 Charge Volume, in³ 637
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Weather: Rain () Sun (x) Cloudy () Temp. °F 84 R.H. % 62
Hole Diameter, in. 9 5/8 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5
35 mm Photo: Before Explosion x After Explosion, x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 16 ft. Crater Diameter, Y-Y Plane 16 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	0	1	2	2	2	3	2	1	1	1	1	0	0	0	0	C
in.	0	0	0	5	10	11	10	1	6	8	5	7	10	7.5	6	1	7	3	0	0	C

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	C	0	1	1	1	2	2	3	2	2	1	1	0	0	0	0	0	0
in.	0	0	9	8	8	0	4	8.5	2	5.5	5	9	6.5	10	6	11	3	0	0	C	C

Remarks:

TABLE IV. CRATERING TEST SAMPLE NUMBER 3, AeReCo 459-23

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 3 Test Sequence No. 4 Date 6-29-68
Explosive Type AeReCo 459-23 Batch No. 2 Charge Wt., lbs. 30 Charge Volume, in³ 603
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 92 R.H. % 40
Hole Diameter, in. 9 23/32 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5
35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion After Explosion

Crater Measurements:

Crater Diameter, X-X Plane 13 ft. Crater Diameter, Y-Y Plane 14 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	2	2	2	2	2	2	1	1	1	1	0	0	0	0	0	0
Depth: in.	0	0	0	0	0	0	1	2	1	1	10	10	4	1.5	0	8	6	0	0	0	0

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	0	0	0	1	1	1	2	2	1	1	0	0	0	0	0	0
Depth: in.	0	0	0	0	3	7	10	7	3	3.5	10	6	4	10	4	11	6	0	0	0	0

Remarks:

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TABLE V. CRATERING TEST SAMPLE NUMBER 4, AeReCo 459-23

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 4 Test Sequence No. 6 Date 7-1-68

Explosive Type AeReCo 459-23 Batch No. 2 Charge Wt., lbs. 30 Charge Volume, in³ 597

Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2

Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 80 R.H. % 62

Hole Diameter, in. 9 1/2 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5

35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 20 ft. Crater Diameter, Y-Y Plane 19 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	1	1	2	2	3	4	4	5	5	5	4	4	3	3	2	2	2	0
Depth: in.	0	1	10	5	11	5.5	11	7	1.5	8	2	6	0	7	1	7.5	2	8	2	7	0

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	1	2	3	3	4	4	4	4	5	4	3	3	2	2	1	1	0	0	0
Depth: in.	0	4	5	1	1	3.5	0	5.5	7	10	2	1.5	10	3	9	3	9	2	6	0	0

Remarks:

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TABLE VI. CRATERING TEST SAMPLE NUMBER 1, AeReCo 475

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 1 Test Sequence No. 7 Date 6-29-68
 Explosive Type AeReCo 475 Batch No. 18 Charge Wt., lbs. 30 Charge Volume, in³ 688
 Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
 Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 82 R.H. % 62
 Hole Diameter, in. 2 5/8 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5
 35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion x After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 13 ft. Crater Diameter, Y-Y Plane 15 ft.

Crater Depth, X-X Plane:

	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Radius, feet																					
Depth: ft.	0	0	0	0	0	0	1	1	1	2	2	2	2	2	1	1	0	0	0	0	0
Depth: in.	0	0	0	0	0	10	1	7	10	0	1	6.5	10	6	11.5	3.5	6	0	0	0	0

Crater Depth, Y-Y Plane:

	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Radius, feet	0	C	0	C	1	1	1	1	1	2	2	2	1	1	1	1	0	C	C	0	0
Depth: ft.	0	0	0	0	2	4	6	8	11	0	1	1	9	5	3	4	5	0	0	0	0
Depth: in.	0	0	0	0	2	4	6	8	11	0	1	1	9	5	3	4	5	0	0	0	0

Remarks:

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TABLE VII. CRATERING TEST SAMPLE NUMBER 2, AeReCo 475

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 2 Test Sequence No. 11 Date 7-1-68
Explosive Type AeReCo 475 Batch No. 2 Charge Wt., lbs. 30 Charge Volume, in³ 671
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 86 R.H.% 62
Hole Diameter, in. 9 5/16 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5
35 mm Photo: Before Explosion After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 17 ft. Crater Diameter, Y-Y Plane 14 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	1	2	2	3	3	3	3	3	2	1	0	0	0	0	0	0
Depth: in.	0	0	0	0	3.5	3	0	2	7	0	6	7	5	0	8	10	2.5	7	8	6	0

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	1	2	2	2	3	3	3	2	2	1	1	0	0	0	0	0
Depth: in.	0	0	0	0	1	2	1.5	4.5	8.5	8	7	4.5	10	1	8	0	5	0	0	0	0

Remarks:

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TABLE VIII. CRATERING TEST SAMPLE NUMBER 3, AeReCo 475

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 3 Test Sequence No. 8 Date 7-1-68

Explosive Type AeReCo 475 Batch No. 3 Charge Wt., lbs. 30 Charge Volume, in³ 683

Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2

Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 84 R.H.% 62

Hole Diameter, in. 9 5/8 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5

35 mm Photo: Before Explosion After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 22 ft. Crater Diameter, Y-Y Plane 22 ft.

Crater Depth, X-X Plane: (See Remarks) East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	2	2	1	1	1	1	0	2	2	1	1	1	1	1	2	2	2	1	1	1	1
in.	2	2	11	10	7	2	11	3	2.5	9	5	4.5	7	11.5	1.5	0	1	10	7.5	8	9

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
in.	8	10	10.5	10	9	3	7	8	6.5	8	5	3	3	4	5	11.5	5	1	5	0	2.5

Remarks: Reference X-X Plane raised 2' 1" and Y-Y Plane 2' 2 1/2" due to formation of mound instead of crater.

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TABLE IX. CRATERING TEST SAMPLE NUMBER 4, AeReCo 475

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 4 Test Sequence No. 2 Date 6-29-68
Explosive Type AeReCo 475 Batch No. 4 Charge Wt., lbs. 30 Charge Volume, in³ 663
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 92 R.H. % 40
Hole Diameter, in. 9 11/16 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5
35 mm Photo: Before Explosion After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 19 ft. Crater Diameter, Y-Y Plane 15 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth: in.	0	0	0	2	6	9	10	7	5	1.75	2.75	-10	-10	-8	-10	-16	-18	-18	-12	-6	-6

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth: in.	0	0	0	0	0	1	6	6	2.5	3	2.75	2	7	8	5	6.5	7.75	6.5	1	0	0

Remarks: Minus dimension for X-X Plane indicates formation of mound above original ground level.

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TABLE X. CRATERING TEST SAMPLE NUMBER 1, TRITONAL

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 1 Test Sequence No. 1 Date 6-29-68

Explosive Type Tritonal Batch No. Charge Wt., lbs. 31.9 Charge Volume, in³ 461

Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2

Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 92 R.H. % 40

Hole Diameter, in. 11 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5

35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion x After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 17 ft. Crater Diameter, Y-Y Plane 16 ft.

Crater Depth, X-X Plane: East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	0	1	2	2	3	4	4	4	4	3	3	2	2	0	0	0	0
Depth: in.	0	0	1	5.25	10.75	6	2.75	9	8	1.75	9	2	3.5	8	0.75	8	1.5	8	0	0	0

Crater Depth, Y-Y Plane: South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	1	2	2	3	4	4	4	4	4	3	3	2	1	1	0	0	0	0
Depth: in.	0	0	0	2.75	0	10.5	2	2.5	5	0	9	2	5	6	7	9	4	8	0	0	0

Remarks: Hole size larger than specified.

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TABLE XI. CRATERING TEST SAMPLE NUMBER 2, TRITONAL

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 2 Test Sequence No. 12 Date 7-1-68

Explosive Type Tritonal Batch No. - Charge Wt., lbs. 31.1 Charge Volume, in³ 461

Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2

Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 86 R.H. % 62

Hole Diameter, in. 9 5/16 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5

35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion x After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 17 ft. Crater Diameter, Y-Y Plane 16 ft.

Crater Depth, X-X Plane:

East West

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	1	0	2	2	2	2	3	3	3	2	2	2	2	1	0	0	0	0
Depth: in.	0	5	11	0	5	0	5.5	9	11	6.5	9.5	5	9	11	5	0	2	0	0	0	0

Crater Depth, Y-Y Plane:

South North

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	0	1	1	2	3	3	3	3	3	3	3	2	2	1	0	0	0	0
Depth: in.	0	0	0	0	2	11	6	6	7	7	9.5	3	3	3	0	9	4	3	11	3.5	0

Remarks:

TABLE XII. CRATERING TEST SAMPLE NUMBER 3, TRITONAL

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 3 Test Sequence No. 5 Date 7-1-68
Explosive Type Tritonal Batch No. - Charge Wt., lbs. 30.9 Charge Volume, in³ 461
Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet () Dry () Damp (x) Weather: Rain () Sun (x) Cloudy () Temp. °F 79 R.H. % 62
Hole Diameter, in. 9 11/16 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5
35 mm Photo: Before Explosion After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 18 ft. Crater Diameter, Y-Y Plane 16 ft.

Crater Depth, X-X Plane:

Radius, feet	East										West										
	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	1	2	2	2	2	2	3	3	4	2	2	2	2	2	1	0	0	0
in.	0	0	7	0	1	1	6.5	6	11	2	5	0	9	7.5	1.5	2	9	2	6	0	0

Crater Depth, Y-Y Plane:

Radius, feet	South										North										
	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	0	1	1	2	2	3	2	3	3	1	2	1	1	1	0	0	0	0	0
in.	0	0	7	1	6	3	6	3	7	0	5	9	10	10.5	8	5.5	6	0	0	0	0

Remarks:

TABLE XIII. CRATERING TEST SAMPLE NUMBER 4, TRITONAL

Data Sheet USAF F08635-68-C-0030 Cratering Tests

Test Sample No. 4 Test Sequence No. 10 Date 7-1-68

Explosive Type Tritonal Batch No. - Charge Wt., lbs. 30.8 Charge Volume, in³ 461

Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2

Ground Conditions: Wet (x) Dry () Damp () Weather: Rain () Sun (x) Cloudy () Temp. °F 85 R.H. % 62

Hole Diameter, in. 9 9/16 Depth to C.G., ft. 7 Hole Depth to Loose Fill Cover, ft. 4.5

35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion x After Explosion x

Crater Measurements:

Crater Diameter, X-X Plane 21 ft. Crater Diameter, Y-Y Plane 22 ft.

Crater Depth, X-X Plane:

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
	0	0	1	1	1	2	3	3	4	5	5	4	4	3	2	2	2	1	1	0	0
Depth: ft.																					
Depth: in.	4	8	2	4	8.5	9	6	5	0	6	2	8.5	2	1	10	10	7	9	3	2.5	0

Crater Depth, Y-Y Plane:

Radius, feet	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10
Depth: ft.	0	0	1	1	2	2	3	3	4	5	5	4	4	4	3	3	3	2	1	1	1
Depth: in.	0	2	3	10	6	7.5	4.5	10	8.5	7	2	9.5	9.5	6	8	3.5	2	6	6	3	0

Remarks:

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SECTION VII

PROCESSING AND LOADING

(C) The ingredients of the explosive were mixed in a vertical mixer with a single bladed planetary mixing arm and heated bowl (180 - 200°F.) Immediately after mixing the mixture was evacuated to remove entrapped gases. The resulting slurry-like mixture did not pour freely but had adequate fluidity to conform to the contour of the vessel into which it was poured. The AeReCo 459-23 was noticeably more viscous than the AeReCo 475. Precaution is required in processing the ingredients to assure that they are well dried and that the cast mixture is moisture free as the urethane reacts with moisture to form carbon dioxide that can cause porosity. Air which contacts the mixture during and after casting must contain less than approximately 40 grains of moisture per pound of dry air. Also, surfaces and subsurfaces of vessels into which the explosive is cast must be moisture free. The mixture begins to set in approximately twenty minutes after mixing and cures hard at 200°F in approximately sixteen hours. Three to ten days are required for curing at ambient temperatures. Eight BLU-31 bombs were loaded under the contract cited in the foreword and samples were cast in cylinders for crater testing. In all formulations MIL A 512-A, Type III, grade F, class 7 aluminum powder and type B, class A RDX were used.

(C) The BLU-31 cases which are more than 6 feet long and 1 foot in diameter presented a filling problem in that there was no access for consolidating the cast mixture by hand making it necessary to depend on its fluidity and gravity. Four of the bomb cases were coated with binder which was allowed to cure before filling with explosive and four were uncoated. There were four filled with AeReCo 475 (two each coated) and four with AeReCo 459-23 (two each coated). In order to evaluate pouring and consolidation prior to filling the bomb cases, mixtures using salt as a substitute for RDX were made and poured into a 6 inch diameter methacrylate tube to simulate pouring conditions. The bomb case has a threaded fuse well in the loading port (also threaded) which necessitated making a special loading fixture with a center hub to hold the fuse well in place and to pour around it. It was found in loading the test mixture that vacuum pouring was necessary. Therefore, the loading fixture was modified to provide continuous evacuation during pouring. The filled bombs were kept at 180°F to 200°F during and after filling to assure adequate fluidity to consolidate the explosive and to speed curing. After filling the bombs, the explosive was capped with neat binder. The quantity of binder required to cap the AeReCo 459-23 filled bombs as well as visual inspection indicated that the explosive in curing had shrunk away from the walls near the filling port. This did not appear to occur with the AeReCo 475. Evacuation of the filled bomb and filling with binder the space left by shrinkage may be superior to precoating with binder. X-Ray photographs of the bombs indicate that lengthwise shrinkage of AeReCo 459-23 occurred which probably caused the pulling away from the inside of the cone shaped nose. The parting lines made by filling with successive batches were discernable on the X-Ray photographs along with some voids in the AeReCo 459-23.

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(C) Where the opening is unobstructed, it is possible to load easily without evacuating. The primary precaution required in loading the cardboard cylinders was that they be coated on the inside with the binder before filling to prevent moisture in the paper from penetrating the mixture after casting. In thin layers, carbon dioxide that forms, escapes the surface without detriment thus allowing coating without difficulty.

(U) Based upon the experience in processing and loading to date, this appears to be the area with the greatest number of unknowns. There is little question that the explosive can be produced by batch process. However, there is good reason to believe that a continuous mixing process will be far more economical and safer. The cost could thus be well below \$1.00 per pound as the present market price of the ingredients is approximately \$0.53 per pound.

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SECTION VIII

DISCUSSION AND RECOMMENDATIONS

(C) The results of the AeReCo explosives evaluation show that in all of the tests performed it is stable under extremes of environment, high impact, and burning. The aluminized version, AeReCo 459-23 equals tritonal in the cratering tests performed. The following are its most significant features:

1. It will withstand 350°F for at least one hour in air at 14.7 psia and 300°F for eight hours.
2. It has excellent storability and is not affected by moisture at any climatic temperature.
3. It equals tritonal in cratering capability in the tests performed. Additional tests are recommended.
4. It has promise of being economical to process (average cost of ingredients is approximately 53 cents per pound.)
5. Processing and loading techniques should be improved and it is recommended that a continuous mixing process be evaluated.

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APPENDIX I

THERMAL STABILITY OF AeReCo 459-23

J. M. Pakulak, Jr.

U.S. Naval Ordnance Test Station

China Lake, California 93555

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U. S. NAVAL ORDNANCE TEST STATION
CHINA LAKE, CALIFORNIA 93555

4532/JMP:mve
Reg. 4532-20
27 March 1967

MEMORANDUM CONFIDENTIAL

From: J. M. Pakulak, Jr., Thermal Analysis Branch (Code 4532)
To: Head, Explosives Research Branch (Code 4541)
Via: Head, Thermal Analysis Branch (Code 4532)

Subj: Thermal Stability of AeReCo-459-23 Explosive (U)
RDX 59 / Al 23 / Binder 18

Ref: (a) Memo 4532/JMP:mve Reg 4532-18 of 2 Mar 1967 (CONFIDENTIAL)

Encl: (1) Table 1. Thermal Stability of AeReCo-459-23 Explosive (CONFIDENTIAL)
(2) Fig. Nos. 1 through 6. DTA Thermal Patterns of AeReCo-459-23 Explosive (CONFIDENTIAL)
(3) Fig. No. 7. Plot of DTA Data for AeReCo-459-23 Explosive (CONFIDENTIAL)
(4) Fig. Nos. 8 through 16. Deflagration Times at Selected Temperatures for AeReCo-459-23 Explosive in Al Tube Ovens (CONFIDENTIAL)
(5) Fig. No. 17. Plot of Deflagration Time Versus Oven Temperature for AeReCo-459-23 and H-6 Explosives (CONFIDENTIAL)

1. This is a progress report on samples of AeReCo-459-23 explosive received from Code 4541 for thermal analysis. Each sample was 3.375 inches in diameter and about 2 inches long. The method of thermal analysis is covered in reference (a). For this report, no thermogravimetric analysis was performed nor isothermal tests on the 3.375-inch diameter samples in air-type ovens. Three isothermal tests were performed on 2-inch cubes in air-type ovens and the data given in enclosure (1).

2. A summary of the DTA data on AeReCo-459-23 explosive is given in enclosure (1). The thermal patterns are shown in enclosure (2). The thermal patterns showed one exothermic peak in the temperature range of 204-223°C for heating rates of 1 to 5°C per minute. A shallow endotherm occurs about when the exotherm starts and continues until about a quarter way or less through exotherm. This endothermic action is believed to be caused by the melting of the RDX present in the explosive. The activation energy was determined by the variable heating rate method and had a value of 37.8 kcal per mole (enclosure (3)). The log frequency factor was 14,432. This is a lower value for the activation energy than normally expected for the decomposition of RDX. The critical temperature was predicted from the DTA data using equation (3) of reference (a). Other data used were:

$$\delta = 2.00$$

$$\rho = 1.7 \text{ g per cm}^3 \text{ (estimated)}$$

$$a = 4.29 \text{ cm (3.375 in. dia.)}$$

$$R = 1.987 \text{ cal per mole } ^\circ\text{K}$$

$$\lambda = 0.00055 \text{ cal per cm-sec-}^\circ\text{C (see test)}$$

$$c = 0.3 \text{ cal per gram (estimated)}$$

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Reg. 4532-20
27 March 1967

Subj: Thermal Stability of AeReCo-459-23 Explosive (U)

The value for λ was derived from the thermal diffusivity (α) measured from the explosive grains in the aluminum tube ovens using equation (7) in reference (a). The values of α determined at different temperatures and tests are given in enclosure (1) and an average value was $0.00108 \text{ cm}^2 \text{ per sec.}$ This data yielded a value of 130°C for the predicted critical temperature of a 3.375-inch in diameter grain.

3. Twelve samples of AeReCo-459-23 explosive were tested in an aluminum sleeve-type oven. The samples were 3.375 inches in diameter and about 2 inches long. Two samples were used in each isothermal test so that the overall length was about four inches. Thermocouples were placed at the center between the samples, at the surface and in the aluminum sleeve reached the selected temperature. The six selected temperatures were $146.1, 153.9, 162.8, 164.4, 173.9$ and 177.2°C and the time-to-deflagration after the aluminum sleeve had come up to temperature were 7.7, 4.3, 2.5, 2.5, 1.2 and 1.35 hours respectively. The individual deflagration tests are shown in enclosure (4) and the data given in enclosure (1). A plot of log time versus oven temperature is shown in enclosure (5) and is used in calculating the experimental critical temperature. In calculating the critical temperature, equations (5) and (6) were used from reference (a). The value of the activation energy for equation (6) was taken from the DTA study. The experimental value of α was used to calculate the reduced time in equation (5). The experimental critical temperature so determined was 145°C . This is about 15°C higher than that predicted by the DTA data on AeReCo-459-23 explosive. The second DTA exotherm from the H-6 explosive predicted a critical temperature of 154°C for this sample diameter which is 9°C higher than the experimental value. The second DTA exotherm in the H-6 explosive is believed to be caused by the decomposition of the RDX present. Although the H-6 explosive has a higher experimental critical temperature for a given size than the AeReCo-459-23 explosive, the actual time-to-deflagration was longer at the higher temperature (170°C region) for AeReCo-459-23 than the H-6 explosive. This may be explained by the fact that the H-6 explosive is in a liquid state during the time of the deflagration study whereas the AeReCo-459-23 explosive is not and that the AeReCo-459-23 explosive has a lower activation energy value. This fact is shown in enclosure (5) where H-6 deflagration data from reference (a) is included for a comparison with the AeReCo-459-23 deflagration data.

4. The AeReCo-459-23 explosive just barely passed the one hour test at 177°C (350°F) whereas the H-6 explosive did not. The reasons for the differences in thermal stability is mentioned above and shown in enclosure (5). The next series of scheduled tests are for the Tritonal explosive followed by tests for RDX only.

JACK M. PAKULAK, JR.

Copy to:

4504

453

4541 (Falterman, Stanton, Stott)

5052 (Ayres)

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TABLE 1. THERMAL STABILITY OF AeReCo-459-23 EXPLOSIVE

(A) DTA Data

<u>Test No.</u>	<u>°C/Min.</u>	<u>Exo. Peak °C</u>	<u>Wt. mg</u>
5-22-6	1.03	204.4	19.5
5-13-5	1.04	202.8	33.7
5-23-1	2.06	212.2	21.4
5-23-3	3.27	217.8	20.0
5-23-5	4.11	221.1	19.2
5-26-1	5.17	223.3	22.8

(B) Chemical and Physical Data

Density = 1.7g per cm³ (estimated)

Heat of Reaction = 300 cal per g (estimated)

Shape factor = 2.00

Gas constant = 1.987 cal per mole-°K

Thermal conductivity = 0.0005 cal per cm-sec-°C

(C) Predicted Critical Temperature (DTA)

<u>Size (inches)</u>	<u>Temperature °C</u>
1	153
2	140
5	123

(D) Deflagration Data

<u>Diameter (inches)</u>	<u>Temperature (°C)</u>	<u>Time-to-Deflagration at temp. (hours)</u>	<u>Oven Type</u>
2-in. cube	120	23*	Air
2-in. cube	151	9.5	Air
2-in. cube	175	2.1	Air
3.375	146.1	7.7	Aluminum
3.375	153.9	4.3	Aluminum
3.375	162.8	2.5	Aluminum
3.375	164.4	2.5	Aluminum
3.375	173.9	1.2	Aluminum
3.375	177.2	1.35	Aluminum

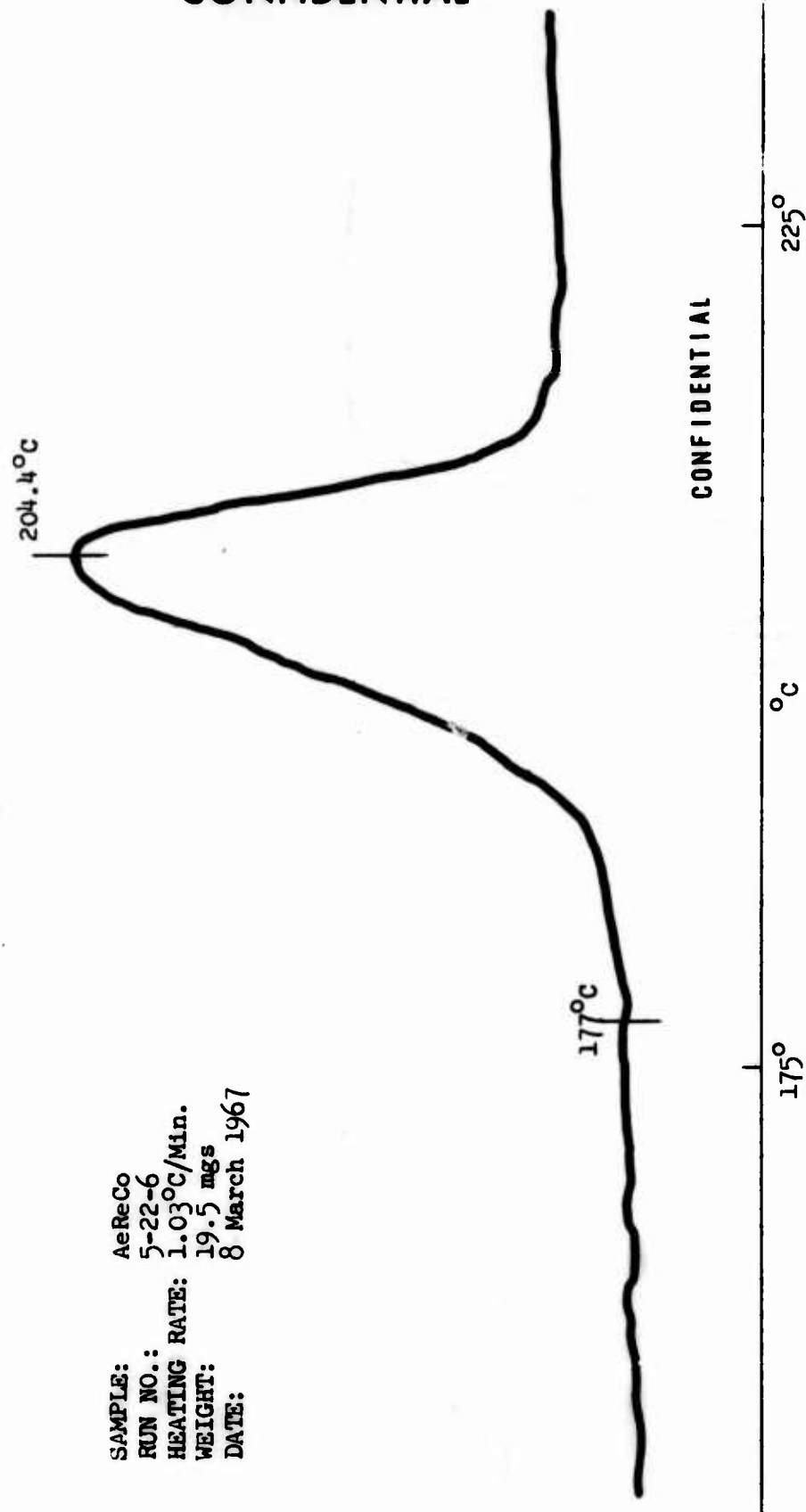
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*No deflagration occurred in 23 hours after which the temperature was raised to about 204°C to terminate the test.

Enclosure (1)

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SAMPLE: AeReCo
RUN NO.: 5-22-6
HEATING RATE: 1.03°C/Min.
WEIGHT: 19.5 mgs
DATE: 8 March 1967

Fig. 1. DTA Thermal Pattern of AeReCo.-459-23 Explosive.

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Enclosure (2)

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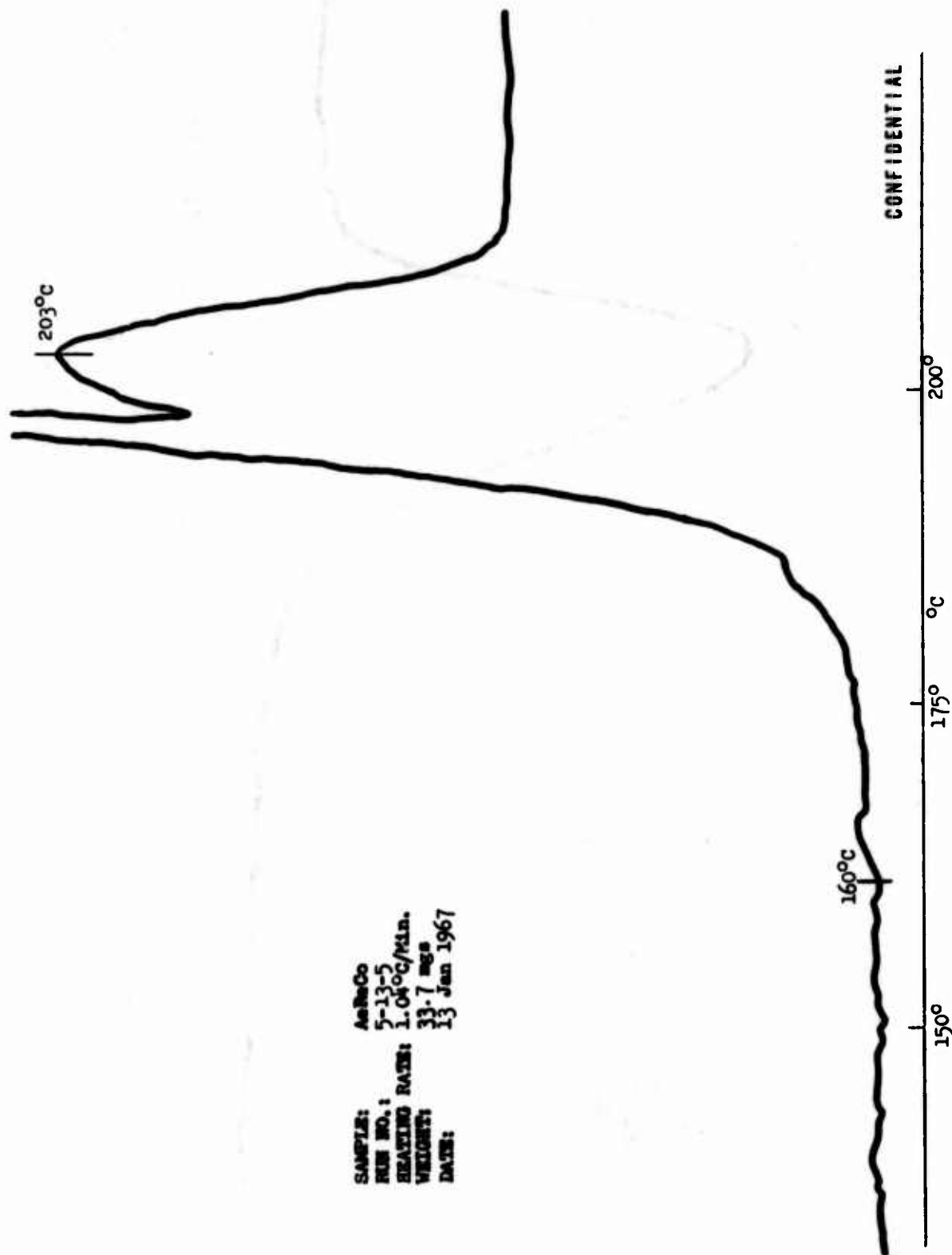
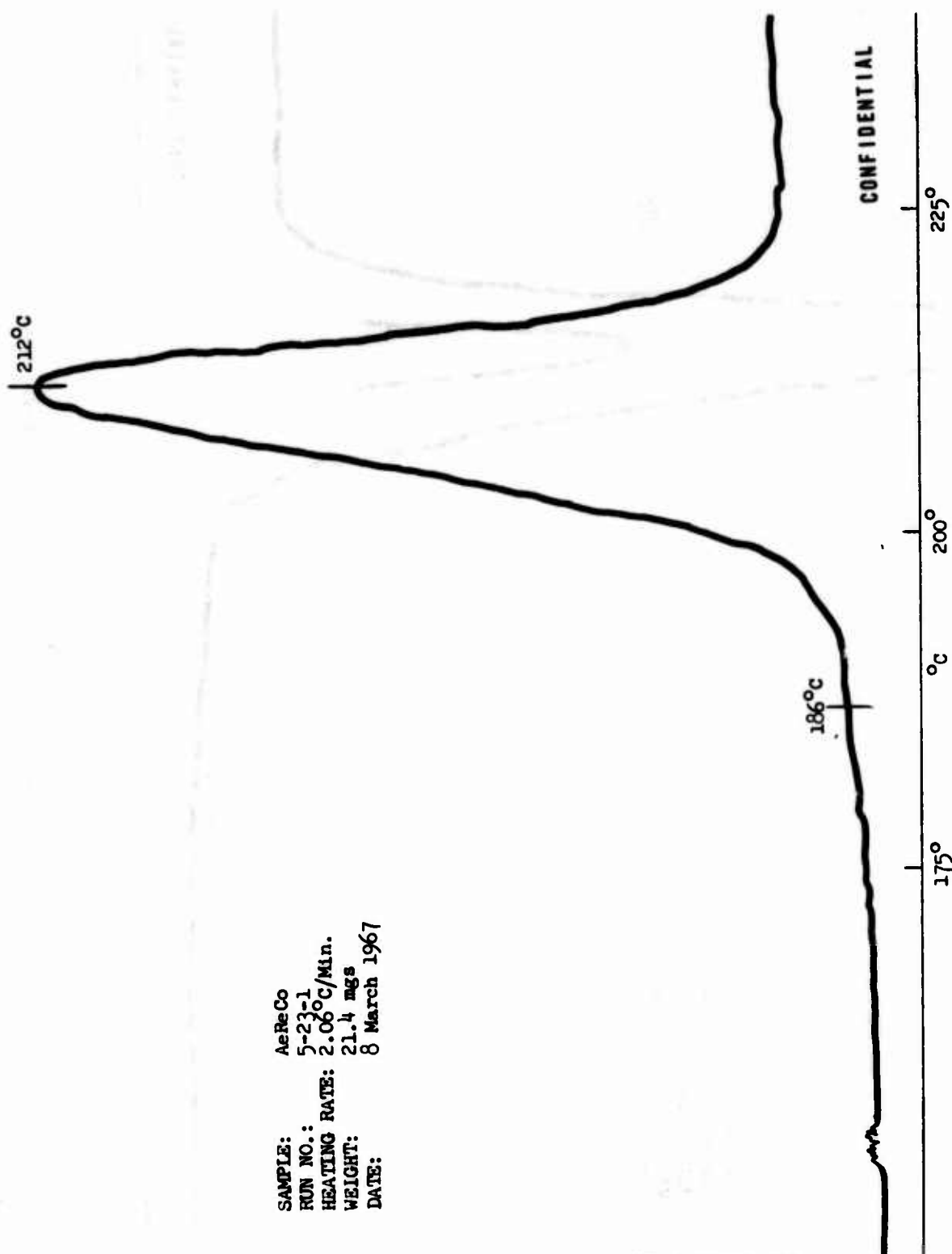


Figure 2 - DTA thermal pattern of AeReCo 459-23 explosive.

Enclosure (2)

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SAMPLE: AeReCo
RUN NO.: 5-23-1
HEATING RATE: 2.06°C/Min.
WEIGHT: 21.4 mgs
DATE: 8 March 1967

Enclosure (2)

Figure 3 - DTA thermal patterns of AeReCo 459-23 explosive.

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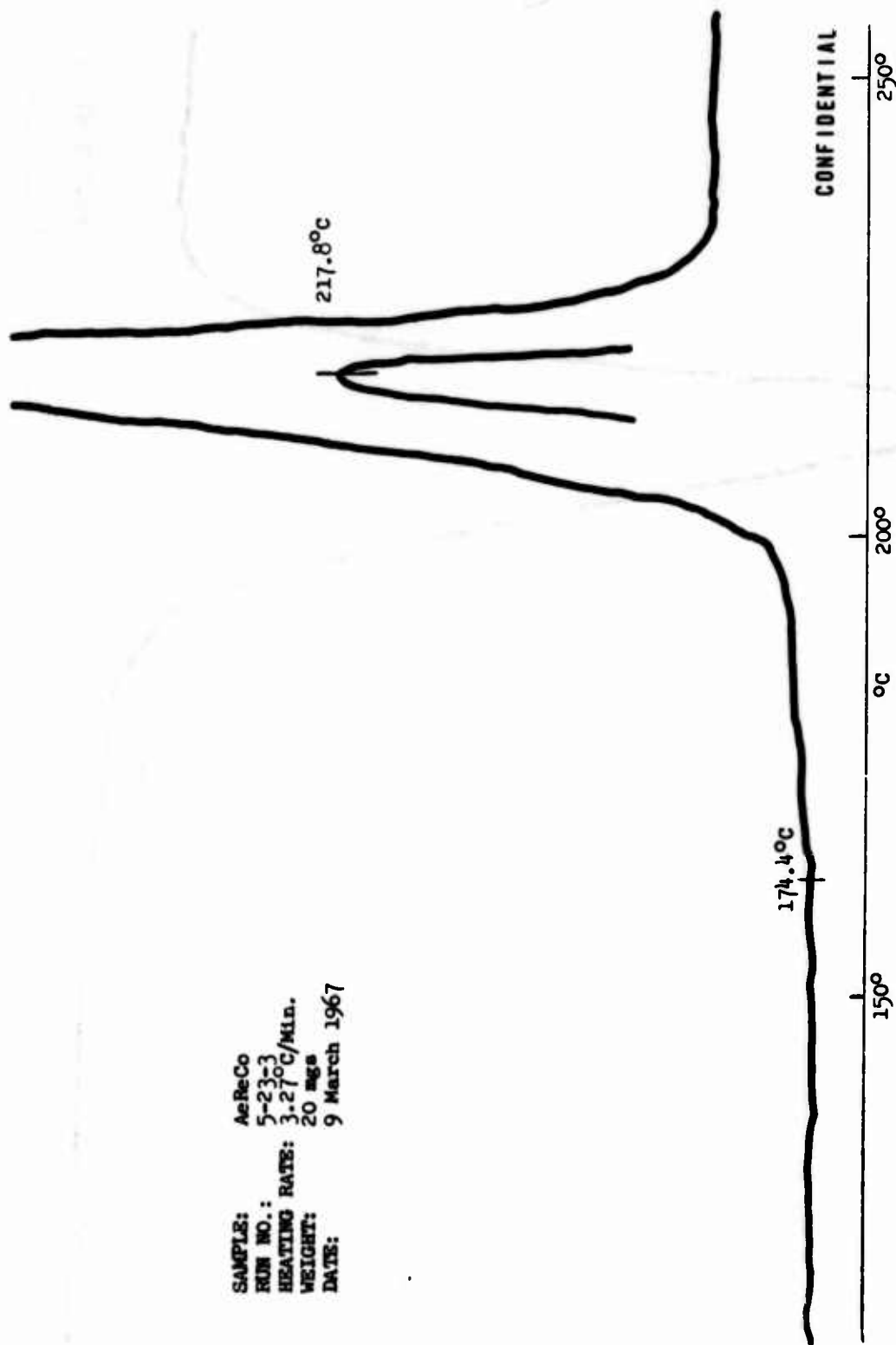
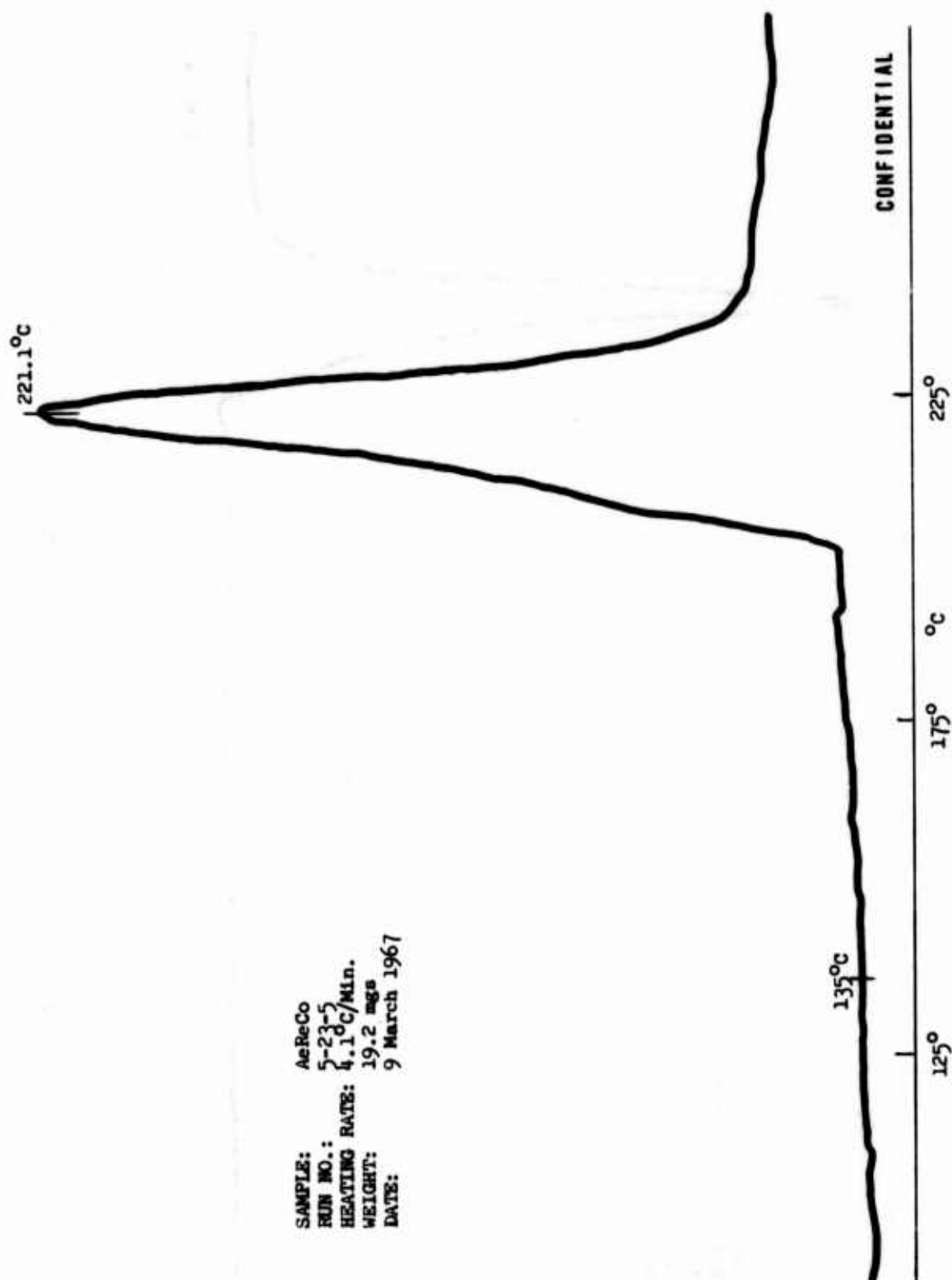


Figure 4 - DTA thermal patterns of AeReCo 459-23 explosive.

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Enclosure (2)

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SAMPLE: AeReCo
RUN NO.: 5-23-5
HEATING RATE: 4.1°C/Min.
WEIGHT: 19.2 mgs
DATE: 9 March 1967

Figure 5 - DTA thermal patterns of AeReCo 459-23 explosive.

Enclosure (2)

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SAMPLE: AeReCo
RUN NO.: 5-26-1
HEATING RATE: 5.17°C/Min.
WEIGHT: 22.8 mgs
DATE: 21 March 1967

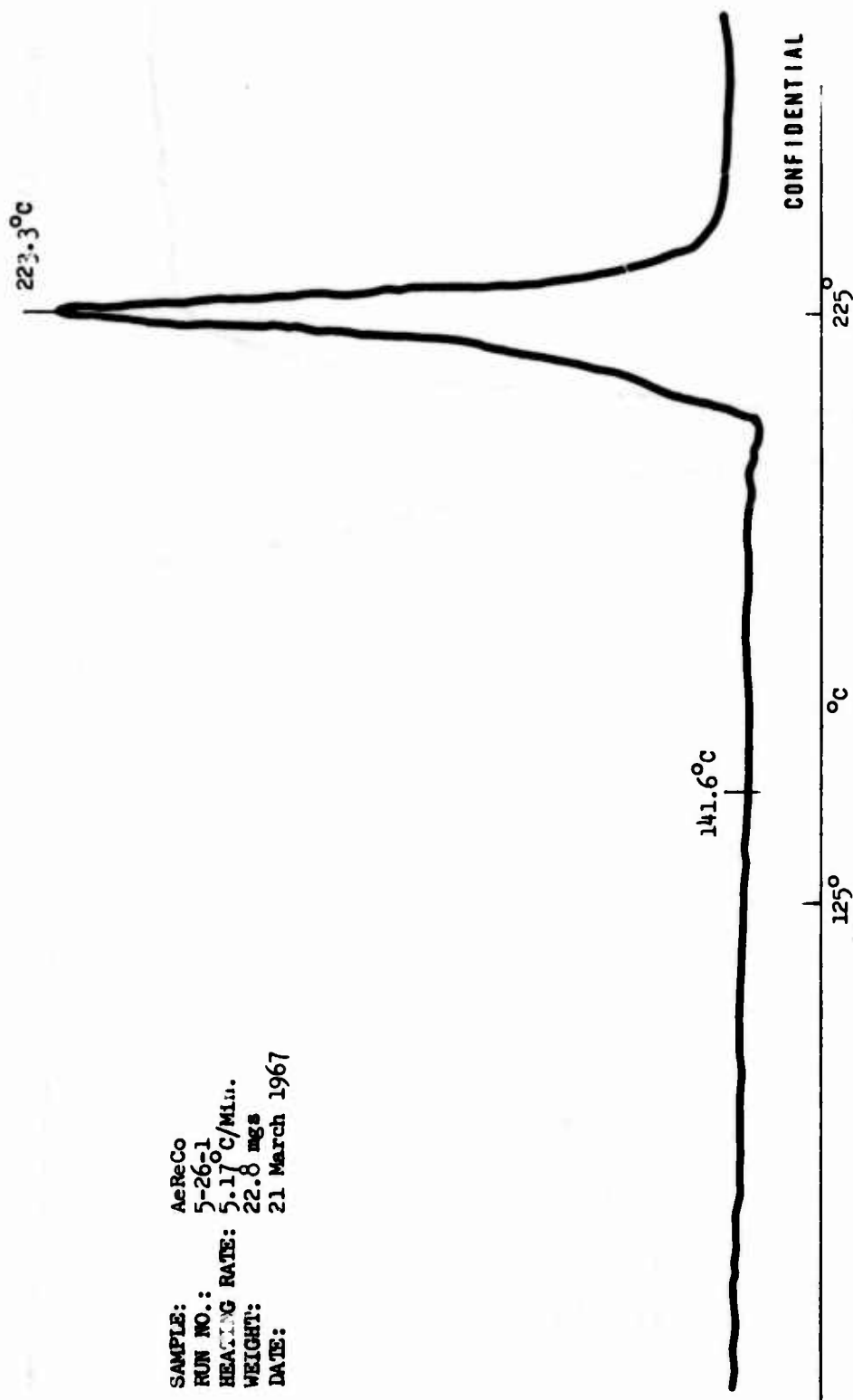


Figure 6 - DTA thermal patterns of AeReCo 459-23 explosive.

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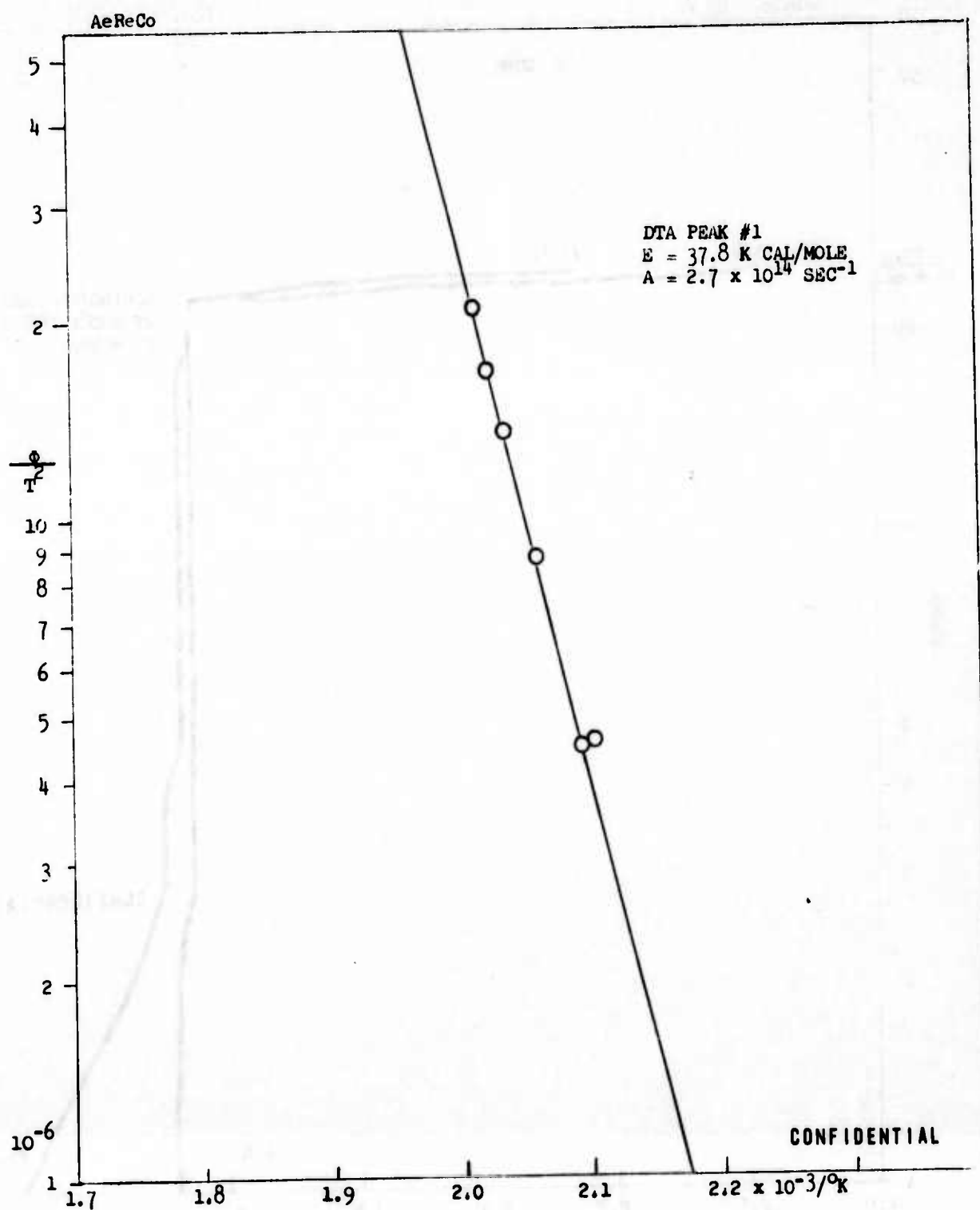


Figure 7 - Plot of DTA for AeReCo 459-23 explosive, enclosure (3).

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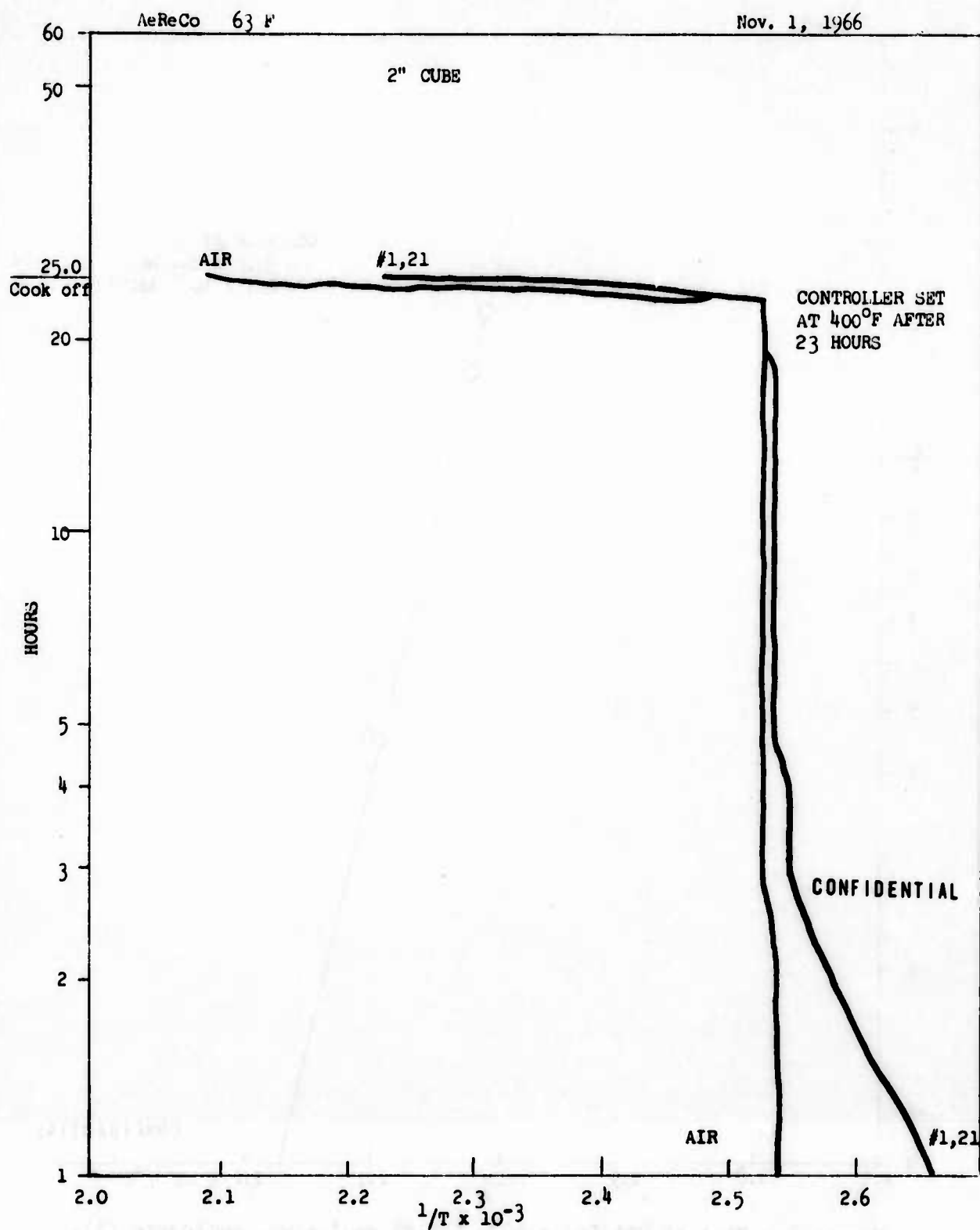


Figure 8 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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AeReCo

Nov. 3, 1966

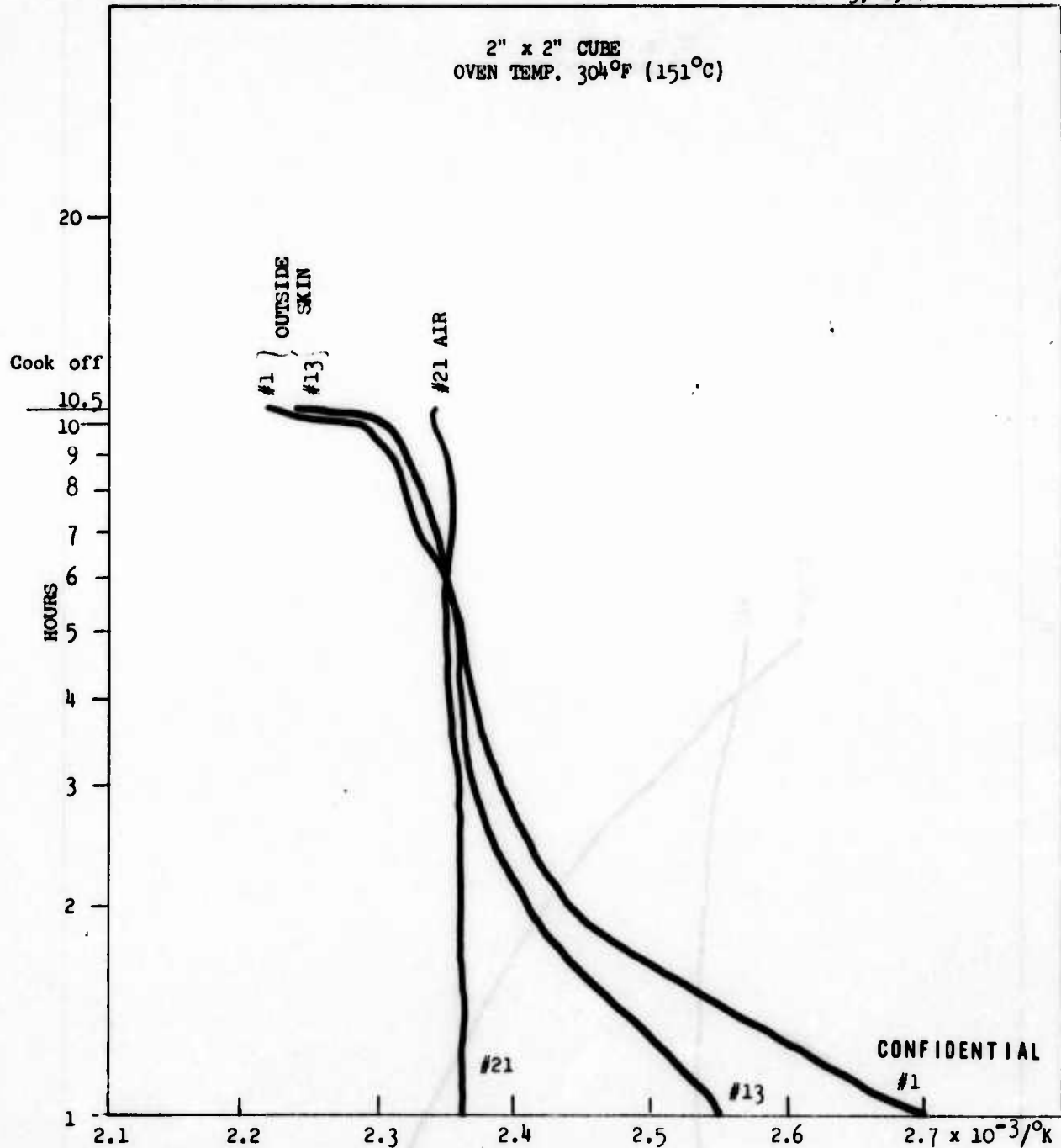


Figure 9 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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AeReCo

Oct. 28, 1966

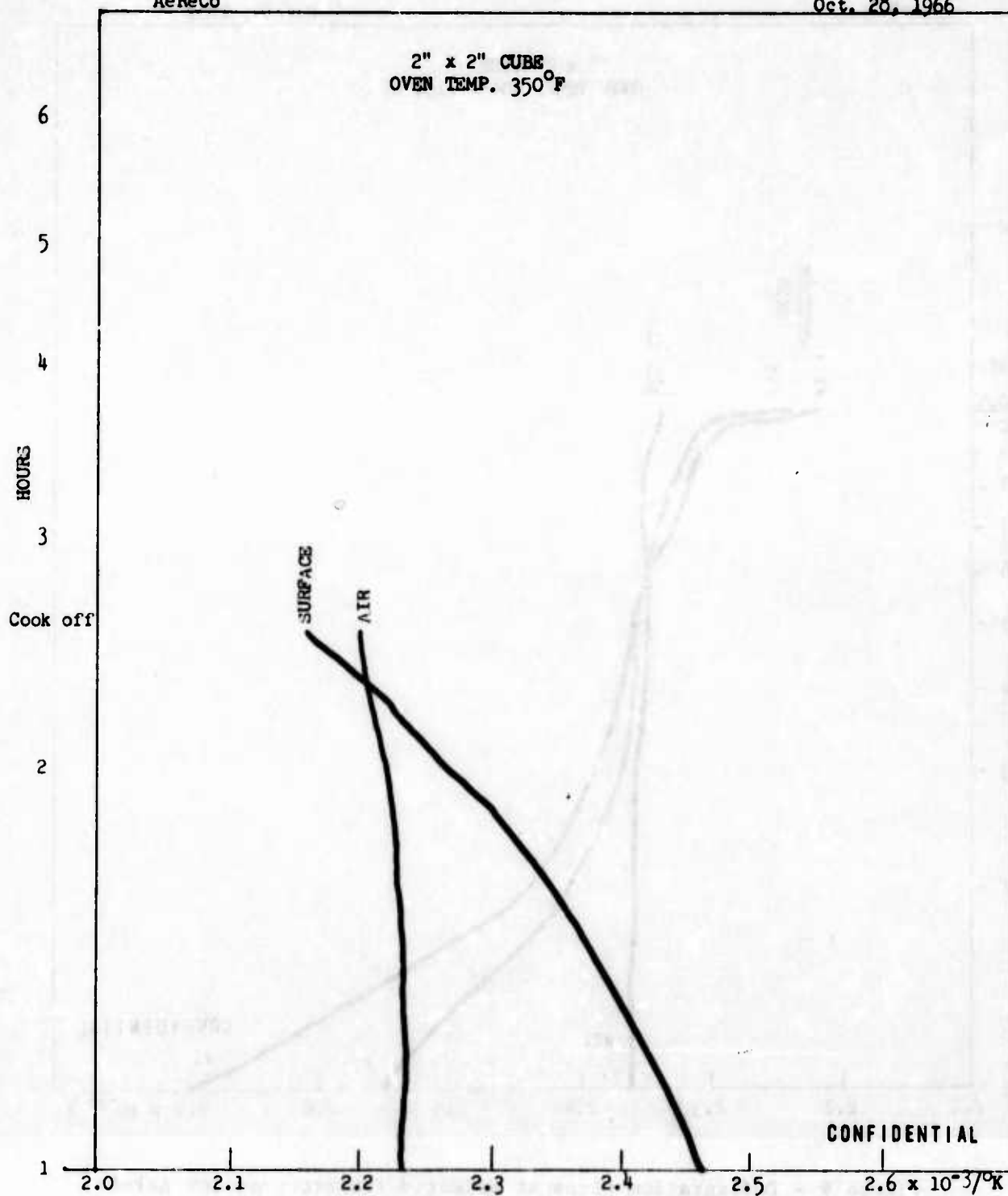


Figure 10 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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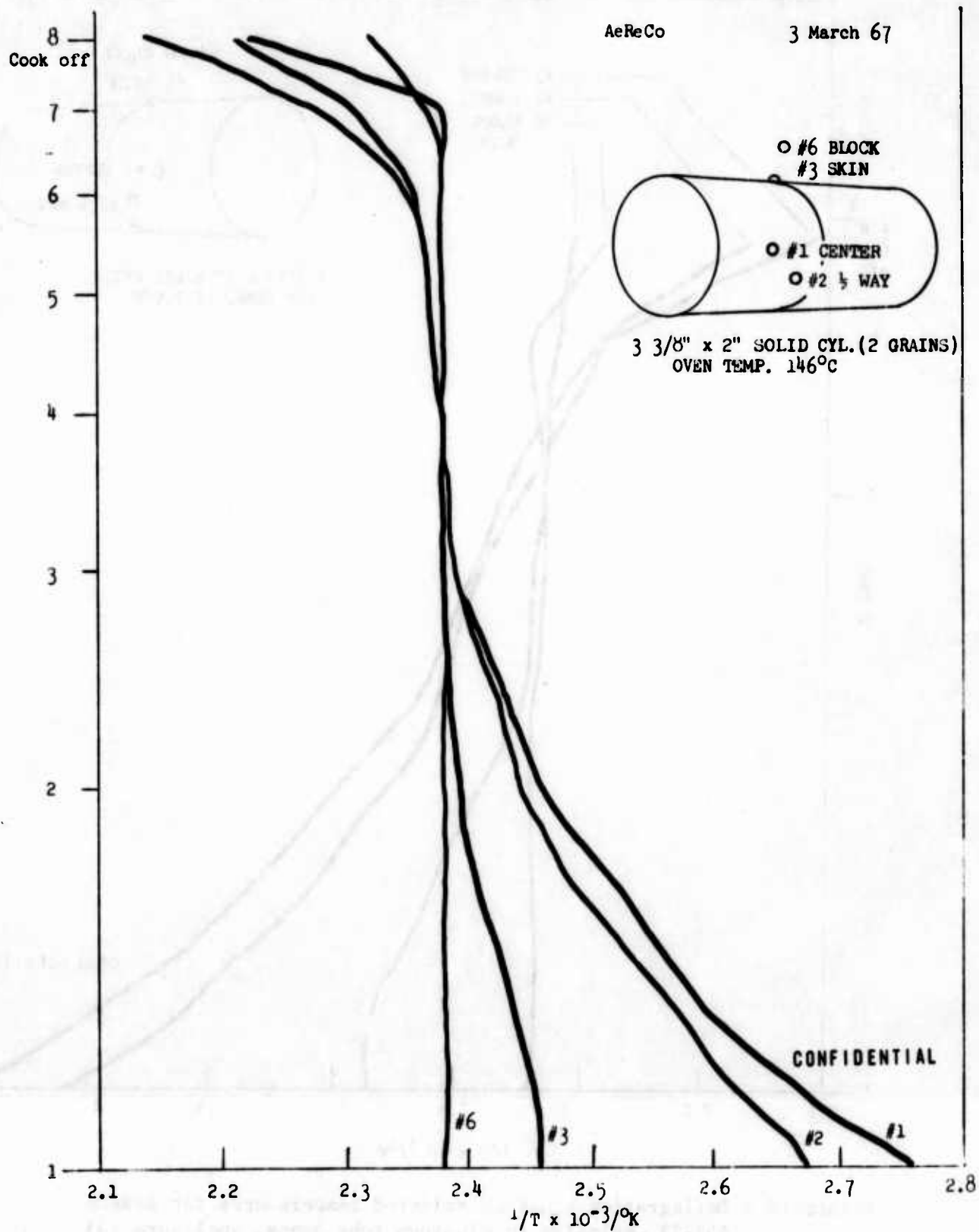


Figure 11 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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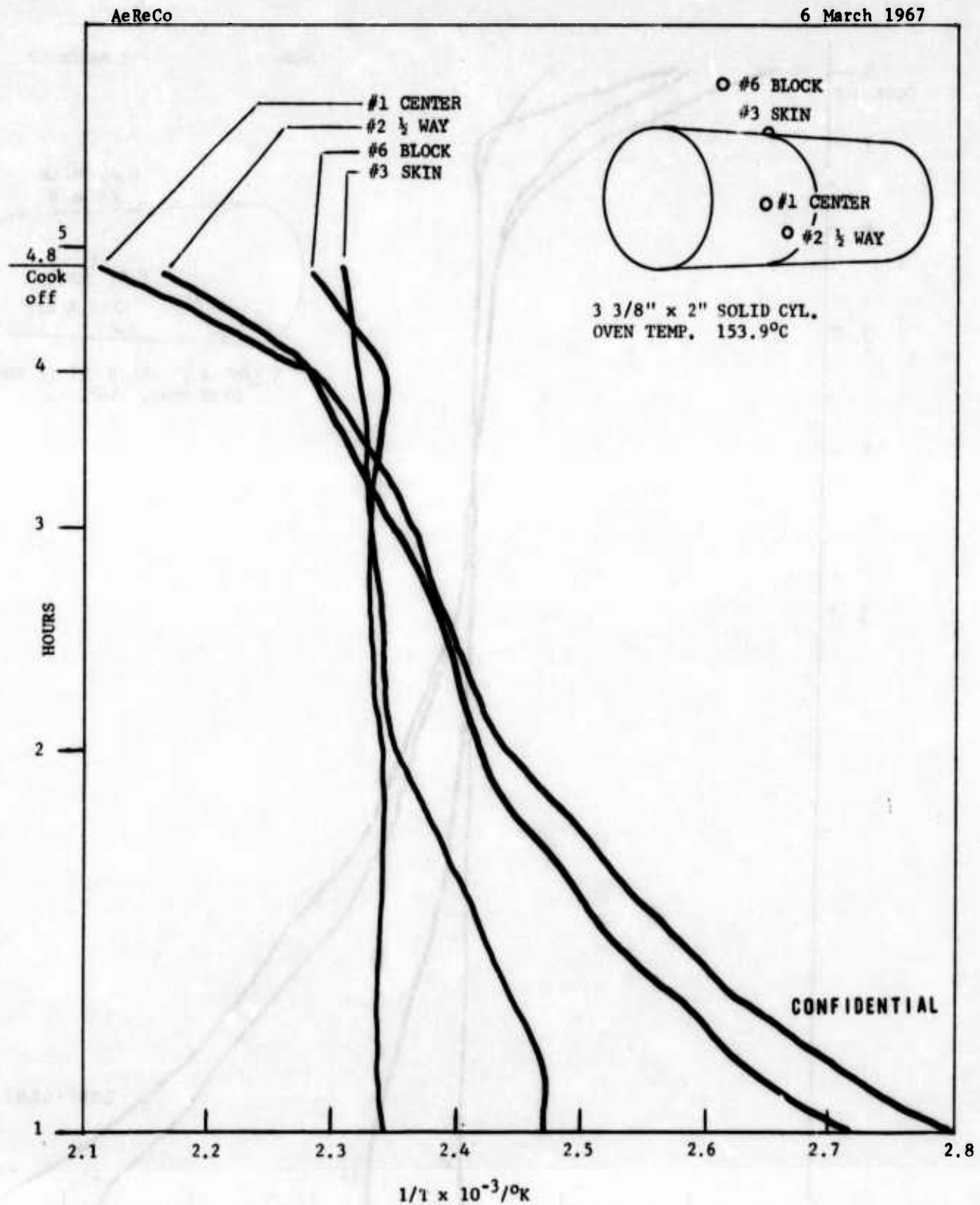


Figure 12 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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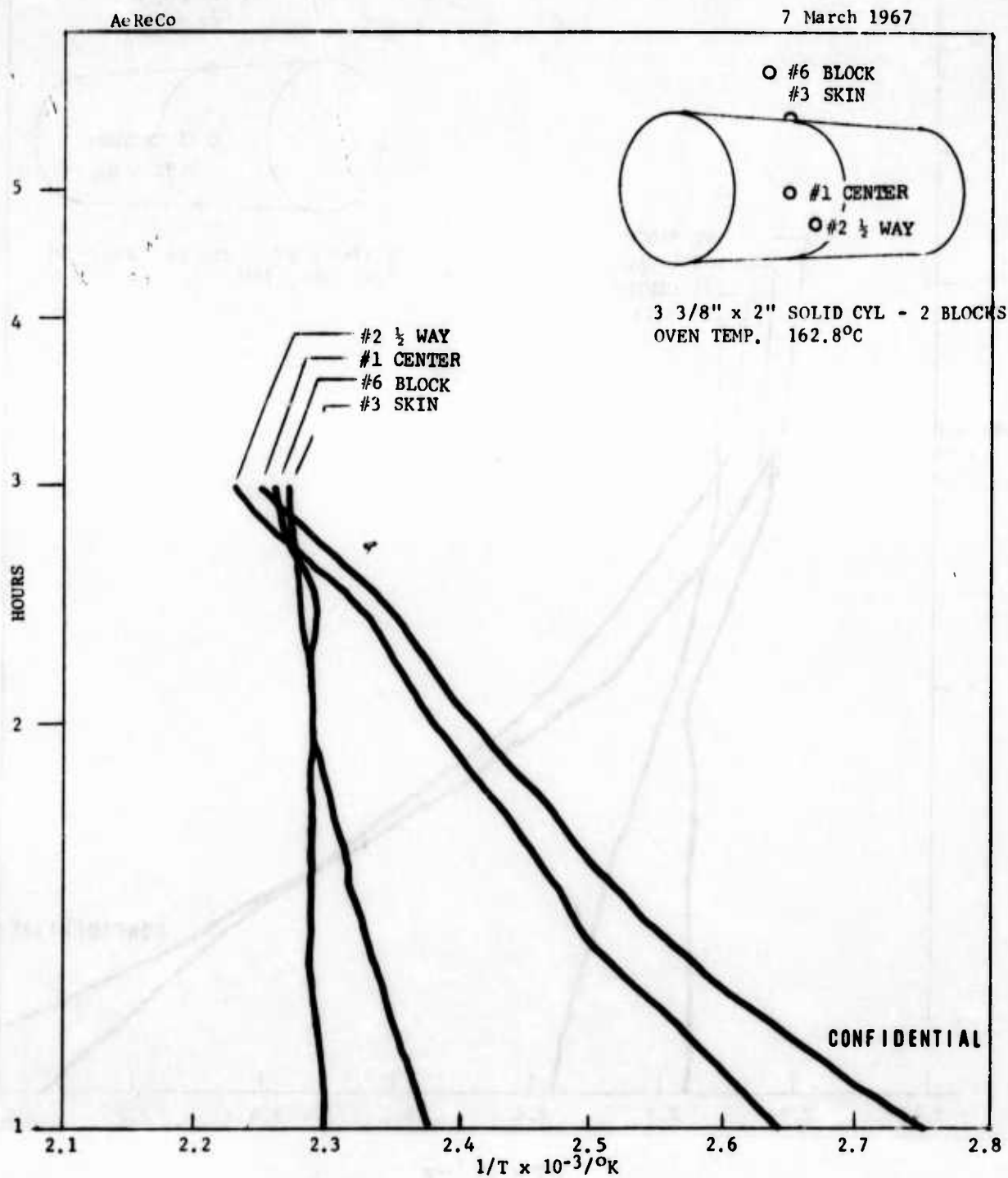


Figure 13 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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AeReCo

3 March 1967

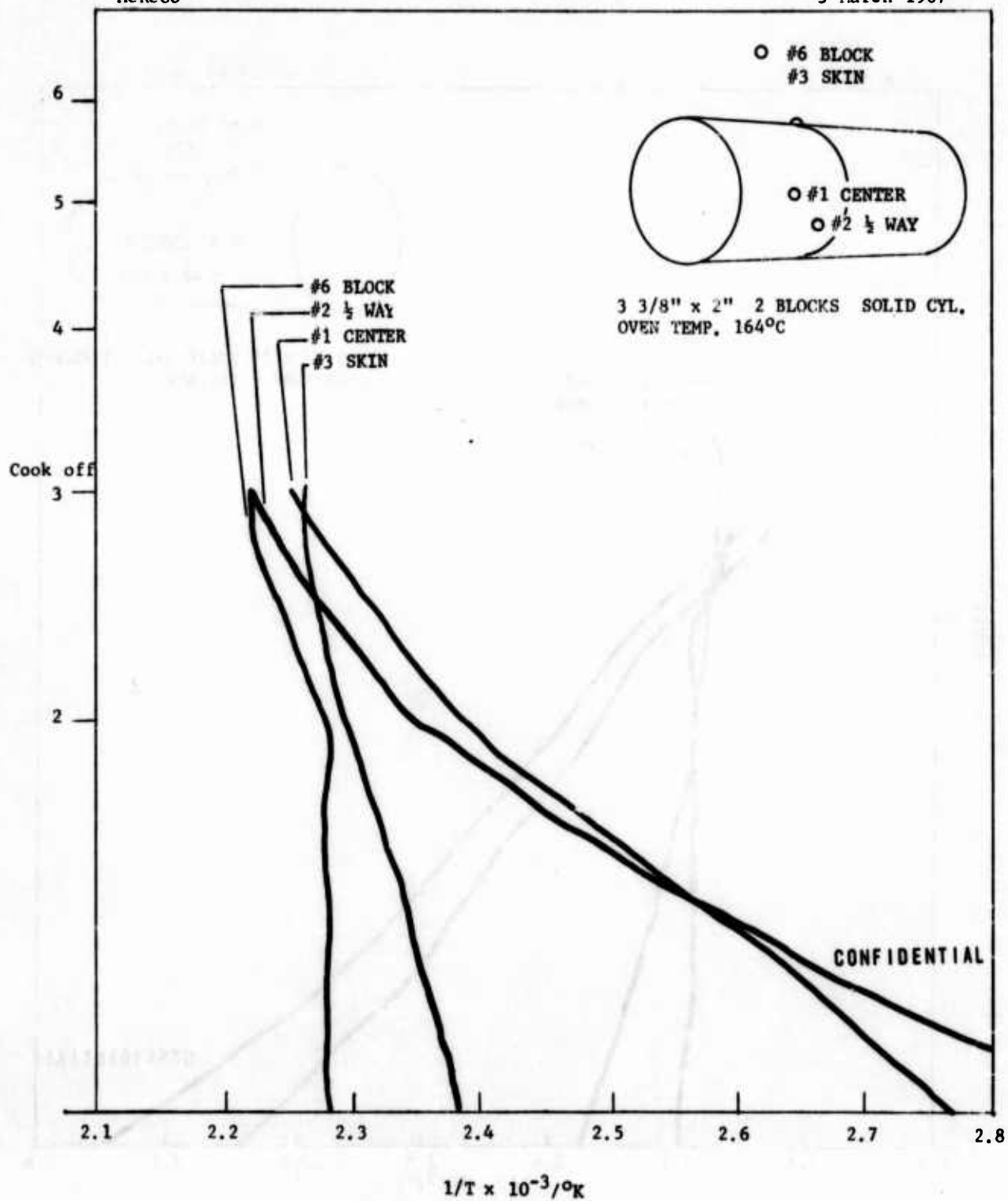


Figure 14 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens.

Enclosure (4)

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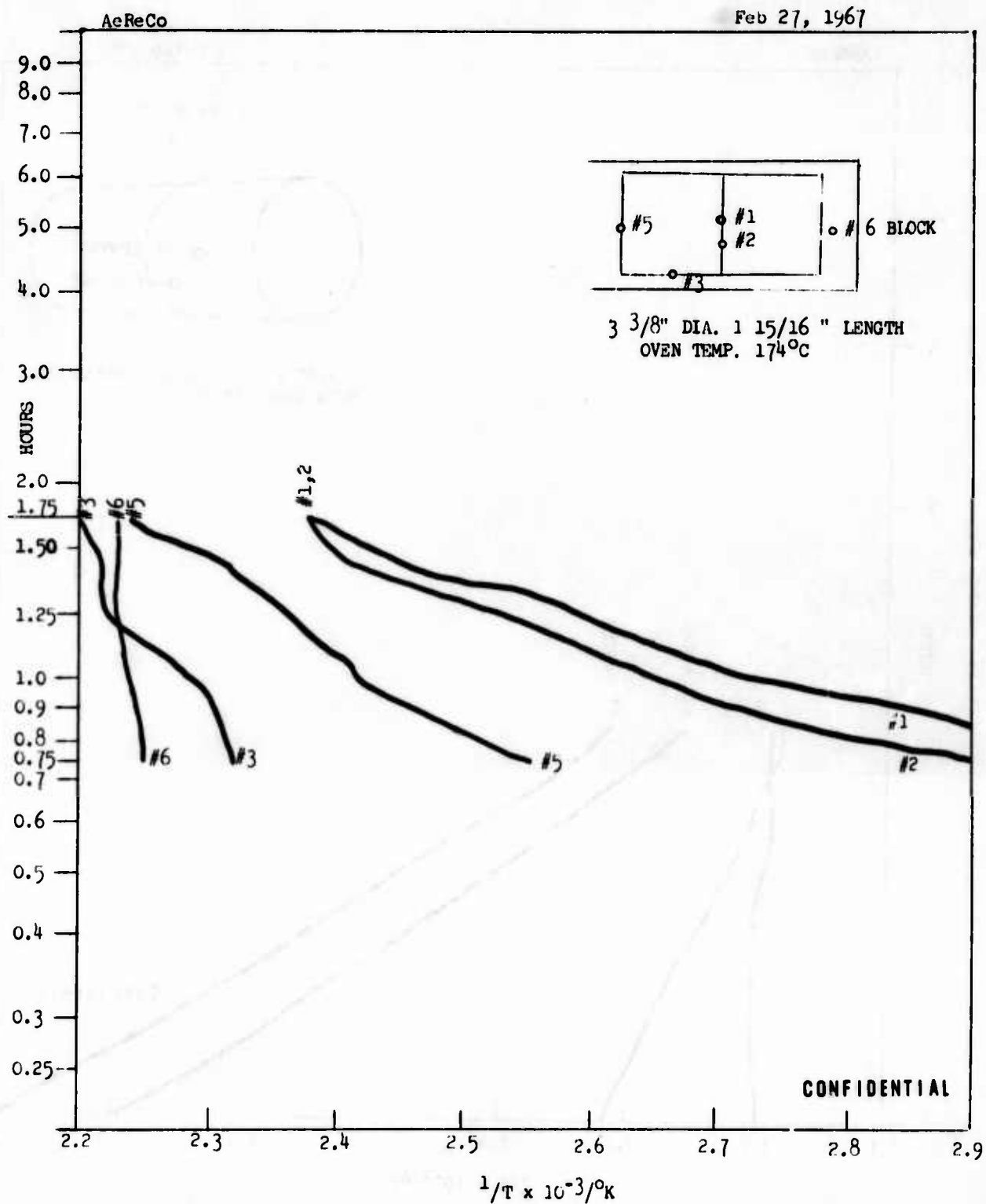


Figure 15 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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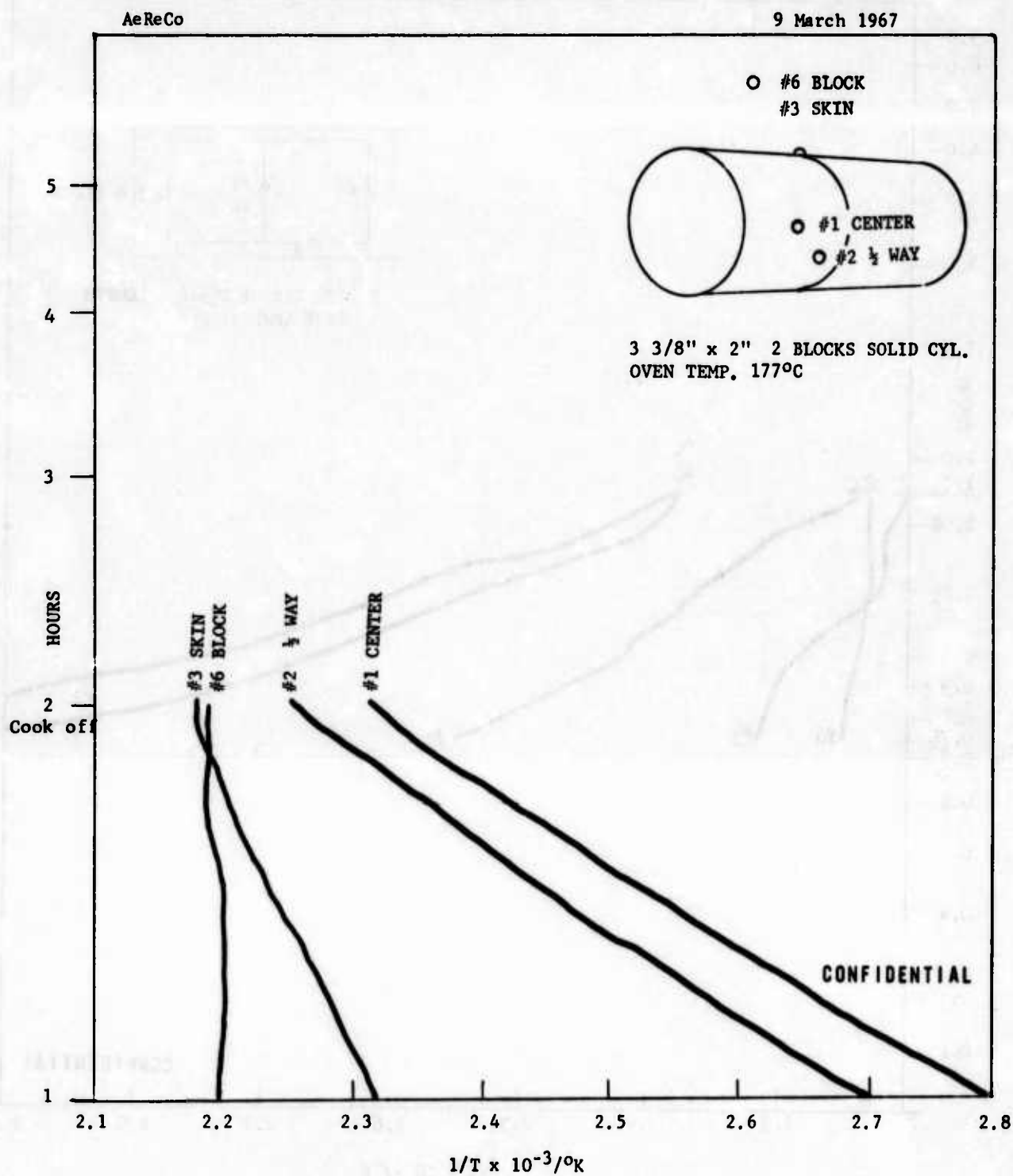


Figure 16 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

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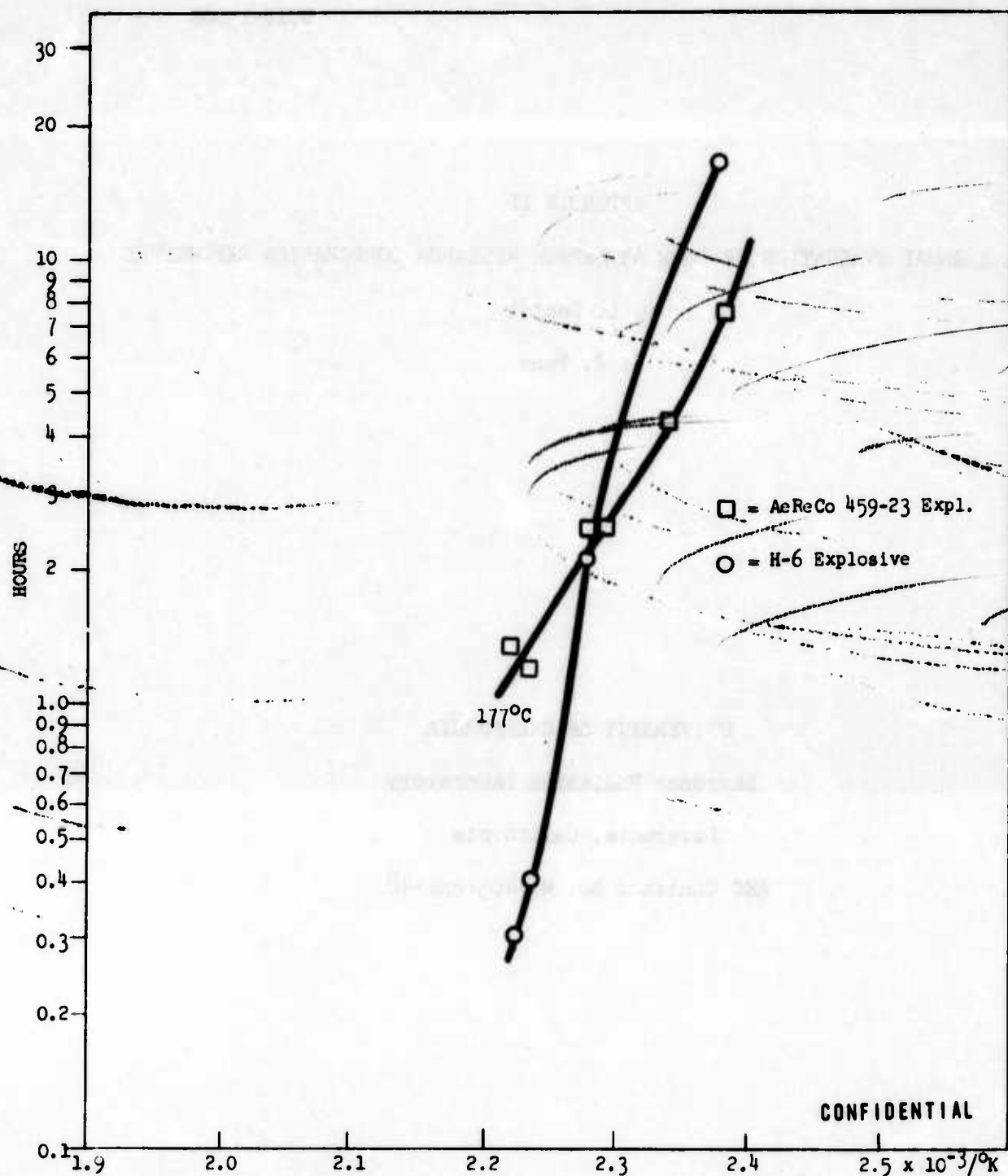


Figure 17 - Plot of deflagration time versus oven temperature for AeReCo 459-23 and H-6 explosives, enclosure (5).

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APPENDIX II

THE THERMAL EVALUATION OF SOME AEROSPACE RESEARCH CORPORATION EXPLOSIVES

D. L. Seaton

A. J. Pane

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory

Livermore, California

AEC Contract No. W-7405-eng-48

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THE THERMAL EVALUATION OF SOME AEROSPACE RESEARCH CORPORATION EXPLOSIVES*

D. L. Seaton and A. J. Pane

University of California, Lawrence Radiation Laboratory

Livermore, California

Three Aerospace Research Corporation explosive formulations were submitted to LRL for small scale thermal testing. These materials, designated as 459-23, 475, and 465-10 are based on RDX, with a polyurethane binder.

Each of these formulations was subjected to the LRL chemical reactivity test and differential thermal analysis. In addition, 459-23 and 475 were examined microscopically on the Koefer hot stage.

Chemical Reactivity Test

In the test a 0.25 g sample, confined in a stainless steel reaction vessel, under approximately 2 atm pressure of He, is heated for 22 hrs. at 120°C. The products are analyzed chromatographically to give both a qualitative as well as quantitative measure of the decomposition products. The results of this test are given in Table 1.

TABLE 1

Explosive	Wt.(g)	Temp. °C	Time Hrs.	Volume (cc STP)				
				N ₂ + O ₂	NO + CO	N ₂ O	CO ₂	Total
459-23	0.2508	120	22	0.005	0.003	0.010	0.013	0.031
459-23	0.2499	120	22	0.008	0.004	0.010	0.013	0.035
465-10	0.2514	120	22	0.010	0.009	0.018	0.022	0.059
465-10	0.2500	120	22	0.010	0.006	0.019	0.024	0.059
475	0.2500	120	22	0.009	0.006	0.013	0.013	0.041
PBX-9010 ^a	0.2498	120	22	0.007	0.001	0.009	0.003	0.020

^aPBX-9010 is 90/10 RDX/Kel F

* This report was prepared as a part of a cooperative effort between the LRL and the AFSC. The details of the agreement and areas of responsibility are contained in correspondence between General B. A. Schriever, Air Force Systems Command, and John S. Foster, Jr., Director, Lawrence Radiation Laboratory.

1) Letter: John S. Foster, Jr., to General B. A. Schriever; Proposal for LRL and AFSC cooperation in certain research and technological developments; May 25, 1965.

2) Letter: General B. A. Schriever to John S. Foster, Jr.; Acceptance of proposal 1; June 30, 1965.

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Differential Thermal Analysis

The DTA curves for these three formulations were generated using NaCl as the reference material and a programmed temperature rise of 11°C/min. Copies of the DTA records are attached. None of the materials show any unusual behavior. The endotherm at ca 200°C is the melting endotherm of RDX. The drifting base line is a characteristic of the instrument and not the explosive.

Koepler Hot Stage Observations

Two of these formulations, 475 and 459-23, were observed on a hot stage microscope as the temperature was raised 4°C/min up to the melting point. Sublimation was observed at ca 150°C, as is expected for RDX. Melting, with subsequent rapid decomposition, occurs at ca 200°C.

Drop Weight Impact Sensitivity

Drop weight impact sensitivities were run on the LRL machine using a 5 kiloweight and Type 12 tools with sandpaper. The results are given in Table 2.

TABLE 2

Explosive	H ₅₀ cm	
HMX Standard	19.5	0.05
459-23	43.8	0.05
465-10	54	0.05
475	56.1	0.06

Conclusions

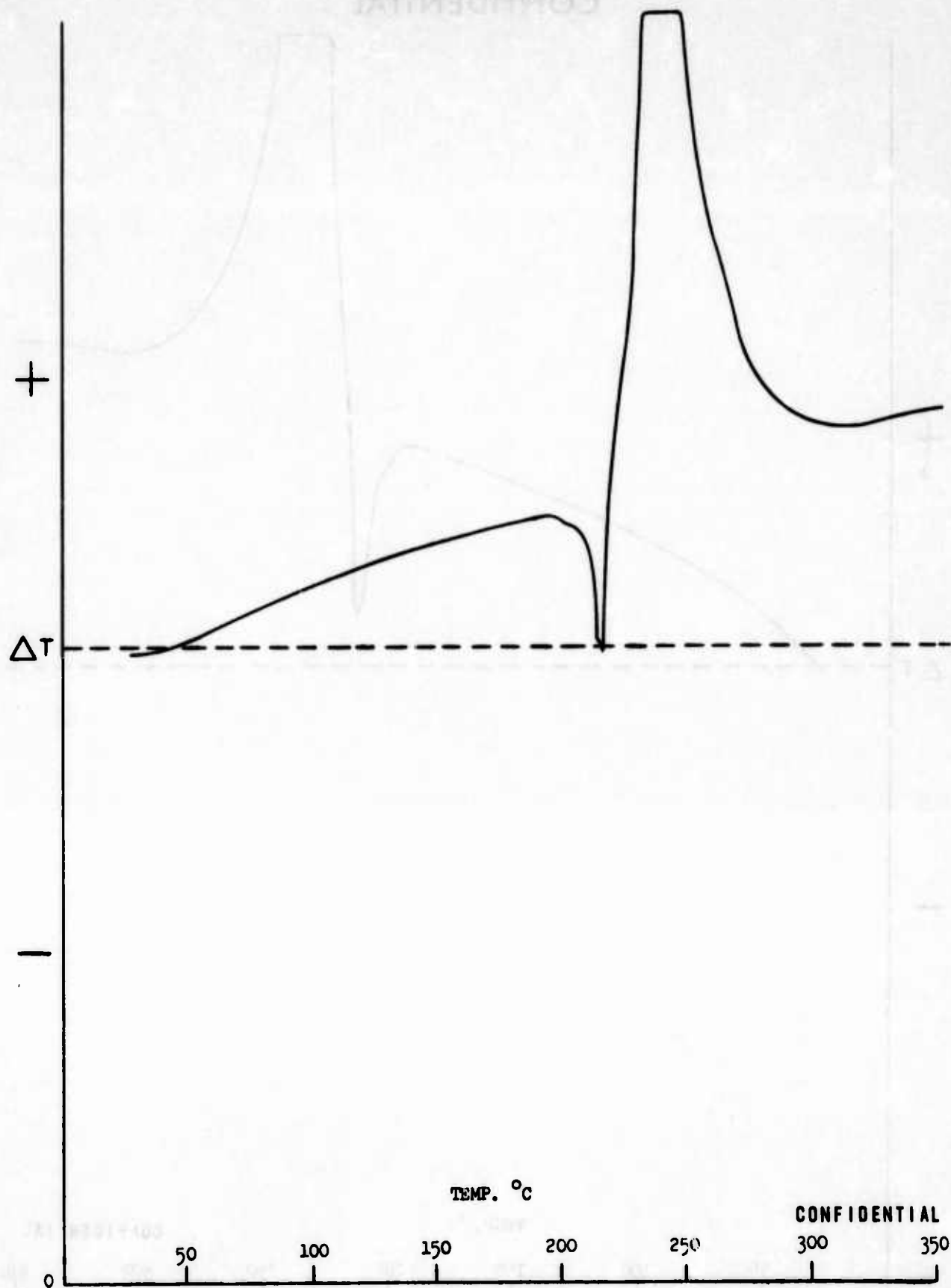
The only test still to be run on these materials is the Henkin or time to explosion test. Unless the times to explosion are greatly reduced, as compared to RDX, the results will not be reported formally.

As expected, from our experience with similar materials, these formulations appear to be quite stable, and there should be no problem with stockpile storage life. Larger scale tests, however, would be required to decide whether or not they could safely meet the high temperature requirements of the Air Force.

Acknowledgment

We wish to thank Mr. E. Ellison for carrying out the impact sensitivity tests.

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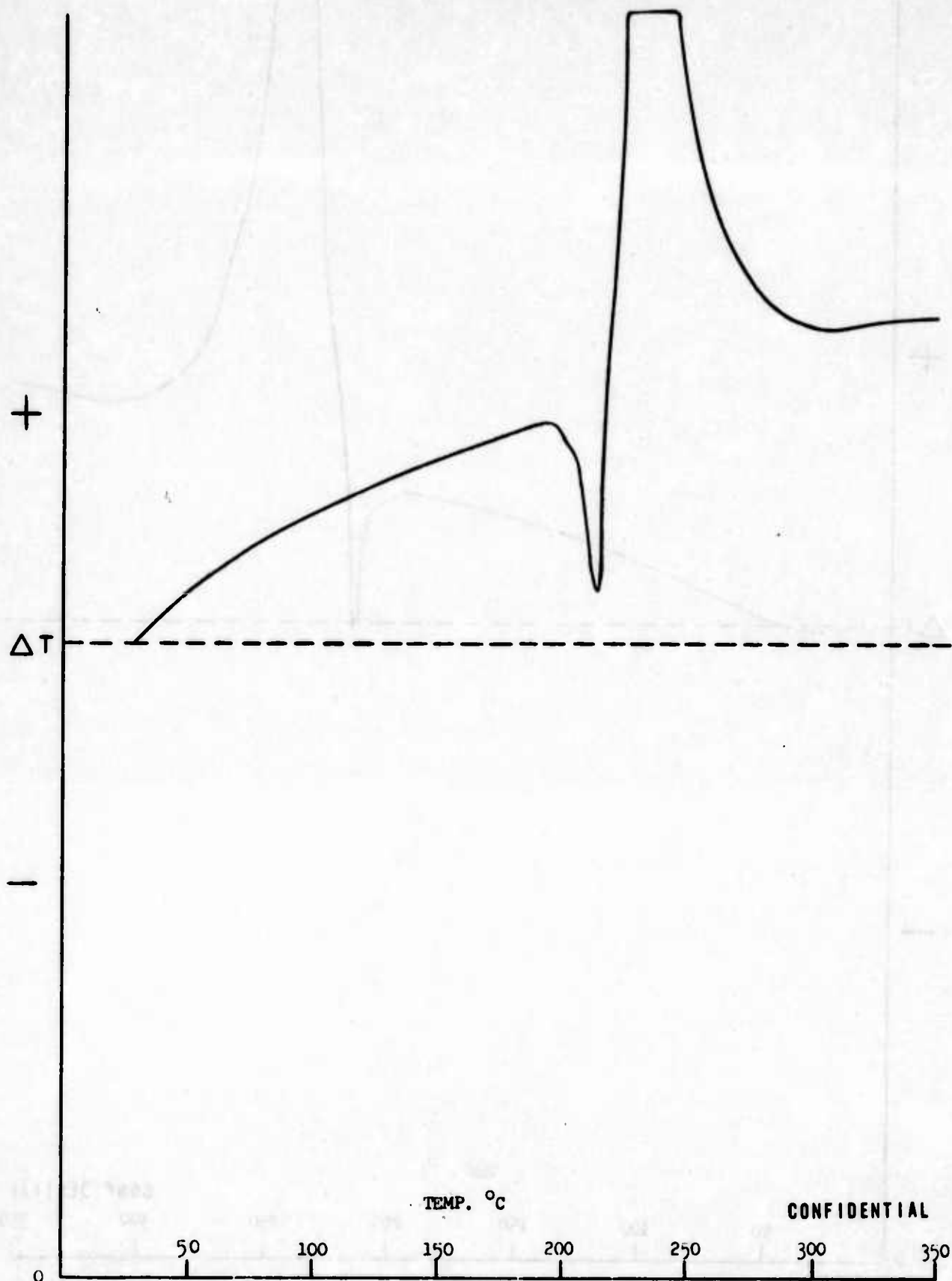


DTA NO. 344, AeReCo NO. 459-23, 11°C/MIN. AT 110 VOLTS, REF: NaCl,
SENS: 0.3 MIN.

65

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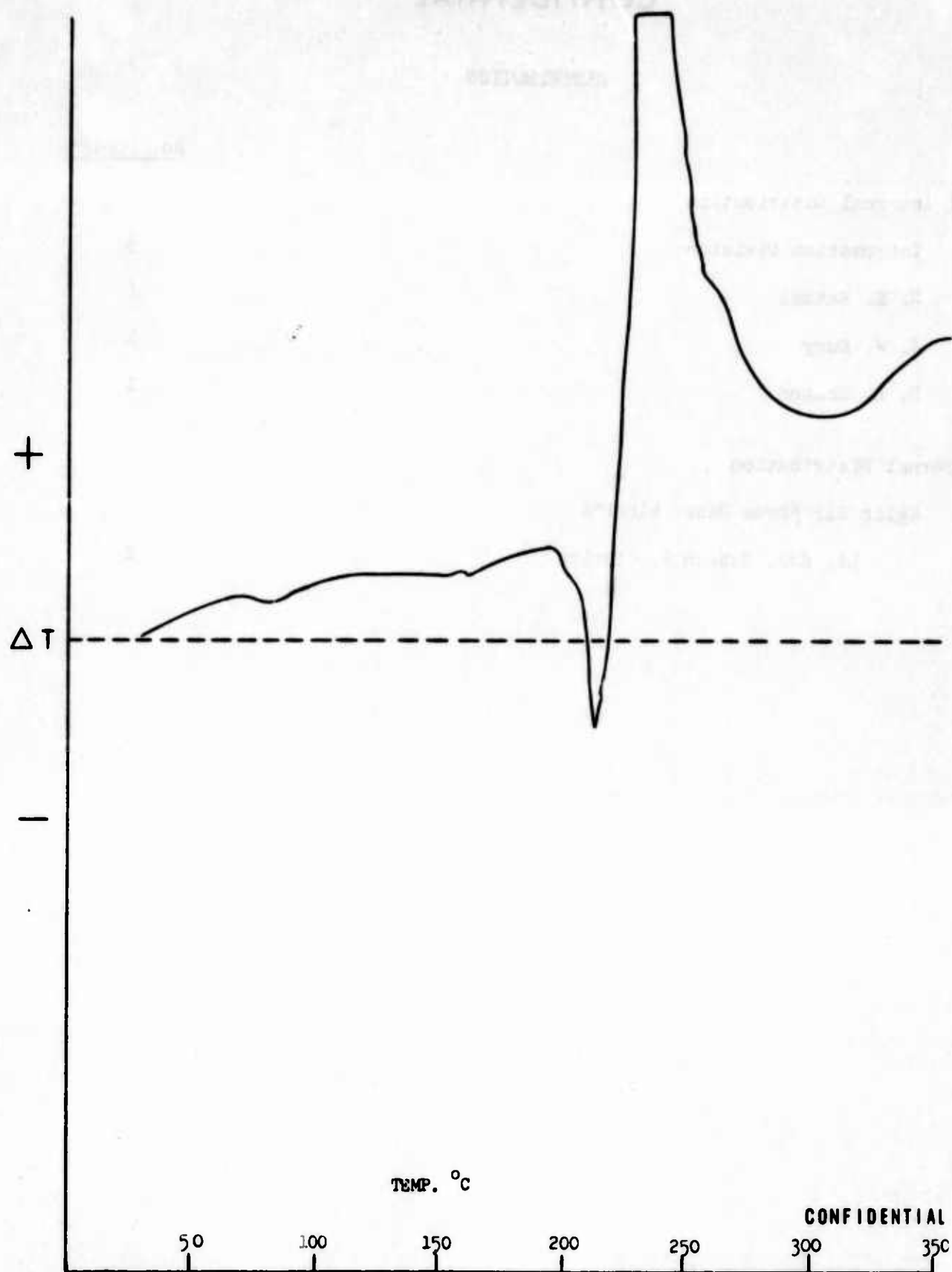


DTA NO. 342, AeReCo NO. 465-10, 11°C/MIN. AT 110 VOLTS, REF: NaCl,
SENS: 0.3 MIN.

66

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DTA NO. 341, AeReCo NO. 475, 11°C/MIN. AT 110 VOLTS, REF: NaCl,
SENS: 0.3 MIN.

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RESEARCH

1954

NO. 100

8 DECEMBER

Report prepared by the U.S. Naval Ordnance Laboratory, White Oak, Maryland, for the U.S. Navy, Division of Ordnance, Silver Spring, Maryland, under contract number ONR-401-57-001-001.

Subject: General Properties of Explosive Materials

1. In this report we have described the general properties of explosives as they relate to the various types of explosives used in the U.S. Navy. The report is intended to provide a general overview of the subject for the benefit of those who are interested in the properties of explosives.

APPENDIX III

RESULTS OF BINDER VACUUM THERMAL STABILITY TESTS

by

U.S. Naval Ordnance Laboratory

Silver Spring, Maryland



**U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK**

SILVER SPRING, MARYLAND

293-10110

10330
Ser 6346

8 DEC 1966

From: Commander, U. S. Naval Ordnance Laboratory, White Oak
To: Director, Air Force Armament Laboratory (AFSC)
Eglin Air Force Base, Florida 32542
Mr. Kyselka, ATWR

Subj: Thermal Stability of Explosive Binders

1. At your request we have tested two binder materials submitted by the Aerospace Research Corporation for vacuum stability. Samples 400A and 400B evolved 1.9 and 0.4 ml gas/g/48 hrs at 150°C respectively.
2. By our criteria both binders were considered to have passed this test satisfactorily.

E. F. SCHREITER

B. E. WHITE
By direction

Copy to:
Aerospace Research Corp.
5454 Jae Valley Rd.
Roanoke, Va., 24014
(Mr. J. T. Hamrick)

APPENDIX IV

RESULTS OF HAZARD CLASSIFICATION TESTS

Tests were performed on AeReCo 459-23 and 475 to determine the hazard classification for handling and shipping. Results of tests by both the Bureau of Explosives and Aerospace Research Corporation are included in this appendix. Drop weight impact sensitivity tests were not performed by either but, were performed by Lawrence Radiation Laboratory and the results are reported in Appendix II of this report.

Both explosives have been classed as Class B explosives for shipment under Department of Transportation regulations.

BUREAU OF EXPLOSIVES

ASSOCIATION OF AMERICAN RAILROADS

REPORT FROM CHEMICAL LABORATORY

T. C. GEORGE, DIRECTOR AND CHIEF INSPECTOR

C. W. SCHULTZ, CHIEF CHEMIST

FILE NUMBER.....15-145

LABORATORY NUMBER.....60166

EDISON, N. J.,.....July 1,.....196 8

Propellant Explosive(Solid), Class D

Ae Re Co 459-23

AEROSPACE RESEARCH CORPORATION

Samples of a material identified as Ae Re Co 459-23 were received from Aerospace Research Corporation of Roanoke, Virginia.

The material was a dense, light gray solid said to contain 59% RDX, 23% aluminum powder and a synthetic rubber binder.

A two inch cube was stable when maintained at 75°C for 48 hours.

When a two inch cube was initiated with a number 8 electric blasting cap it did not explode or ignite. This test was repeated with the same result.

Several two inch cubes were placed in contact with each other on a bed of kerosene-soaked sawdust which was ignited. When the fire reached the samples they did not really burn but appeared to carbonize and decompose.

Material represented by these samples is properly described as Propellant Explosive(Solid), Class B and classed as Class B Explosive under the DOT Regulations.

C.W. Schultz

(JAD)

BUREAU OF EXPLOSIVES

ASSOCIATION OF AMERICAN RAILROADS

REPORT FROM CHEMICAL LABORATORY

T. C. GEORGE, DIRECTOR AND CHIEF INSPECTOR

C. W. SCHULTZ, CHIEF CHEMIST

FILE NUMBER.....15-145
LABORATORY NUMBER.....60165

EDISON, N. J.,.....July 1,.....196 8

Propellant Explosive (Solid), Class B

Ae Re Co 475

AEROSPACE RESEARCH CORPORATION

Samples of a material identified as Ae Re Co 475 were received from Aerospace Research Corporation of Roanoke, Virginia.

The material was a dense white solid said to contain 75% RDX in a synthetic rubber binder.

A two inch cube was stable when maintained at 75°C for 48 hours.

When a two inch cube was initiated with a number 8 electric blasting cap it did not explode, ignite or break apart. This test was repeated with the same results except that about half the cube was blown away by the cap.

Several two inch cubes were placed in contact with each other on a bed of kerosene-soaked sawdust which was ignited. When the fire reached the samples they did not really burn but appeared to carbonize and decompose.

Material represented by these samples is properly described as Propellant Explosive(Solid), Class B and classed as Class B Explosives under the DOT Regulations.

C.W. Schultz

(JAD)

Date May 23, 1968

Sponsoring Agency Department of the Air Force APCC, AFSC, Eglin AFB, Fla.

Contract No. AF F08635-68-C-0030

Propellant Identity (Type No.) Aerospace Research Corp. AsReCo 475

Propellant Spec. Not available Batch No. 1

Mfg. Date 5-20-68

Detonation Test

	Exploded		Burned		Fragmented	
	Yes	No	Yes	No	Yes	No
No. 8 Blasting Cap Test I	—	<u>X</u>	—	<u>X</u>	—	<u>X</u>
Test II	—	<u>X</u>	—	<u>X</u>	—	<u>X</u>
Test III	—	<u>X</u>	—	<u>X</u>	<u>X</u>	<u>X</u>
Test IV	—	<u>X</u>	—	<u>X</u>	—	<u>X</u>
Test V	—	<u>X</u>	—	<u>X</u>	—	<u>X</u>

Samples: Five 2-inch cubes.

Test: One blasting cap per sample.

Ignition & Unconfined Burning Test

	Exploded		Average Burning Time Seconds
	Yes	No	
One 2-inch cube	—	<u>X</u>	<u>4 min.</u>
One 2-inch cube	—	<u>X</u>	<u>3 min. 21 sec.</u>
Four 2-inch cubes	—	<u>X</u>	<u>4 min. 56 sec.</u>

Samples: Six 2-inch cubes.

Test: Ignite & burn unconfined.

Thermal Stability Test

	Explosion		Ignition		Change in Configuration	
	Yes	No	Yes	No	Yes	No
One 2-inch cube	—	<u>X</u>	—	<u>X</u>	—	<u>X</u>

Samples: One 2-inch cube

Test: 48 hours at 75° C. in vented oven.

Card Gap Test

By comparison

50% Value

(No. of Cards) over 70

Impact Sensitivity Test

Bureau of Explosives Impact Apparatus

Ten 3 1/2" (± 1/16") Drop Test 10 Trials			Ten 10" (± 1/16") Drop Test 10 Trials		
No. of Trials Exhibiting			No. of Trials Exhibiting		
Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise	Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise

Approved:

Test Director LCR

Test Department Head LCR

Assigned Classification	
ICC Forbidden	
ICC Restricted*	
ICC Class A	
ICC Class B	

DOD Approval Witnessing

Signature [Signature]

Title QAR

Organization DCAS, Pittsburgh

*Shipping Instructions are to be requested from ICJ (para 3-13a(2)).

Figure 1. Sample summary data sheet.

AGO 7881A

Date May 23, 1968
 Sponsoring Agency Department of the Air Force AFCC, AFSC Eglin AFB, Fla.
 Contract No. AF F08635-68-G-0030
 Propellant Identity (Type No.) Aerospace Research Corp. AeReCo 459-23
 Propellant Spec. Not available Batch No. 1
 Mfg. Date 5-20-68

Detonation Test

	Explored		Burned		Fragmented	
	Yes	No	Yes	No	Yes	No
No. 8 Blasting Cap Test I	—	X	—	X	—	X
Test II	—	X	—	X	—	X
Test III	—	X	—	X	—	X
Test IV	—	X	—	X	—	X
Test V	—	X	—	X	—	X

Samples: Five 2-inch cubes.

Test: One blasting cap per sample.

Ignition & Unconfined Burning Test

	Exploded		Average Burning Time Seconds
	Yes	No	
One 2-inch cube	—	X	5 min. 17 sec.
One 2-inch cube	—	X	5 min. 46 sec.
Four 2-inch cubes	—	X	5 min. 18 sec.

Samples: Six 2-inch cubes.

Test: Ignite & burn unconfined.

Thermal Stability Test

	Explosion		Ignition		Change in Configuration	
	Yes	No	Yes	No	Yes	No
One 2-inch cube	—	X	—	X	—	X

Samples: One 2-inch cube

Test: 48 hours at 75° C. in vented oven.

Card Gap Test

By comparison

50% Value

(No. of Cards)

over 70

Impact Sensitivity Test

Bureau of Explosives Impact Apparatus

Ten 3 1/2" (± 1/16") Drop Test
10 Trials

Ten 10" (± 1/16") Drop Test
10 Trials

No. of Trials Exhibiting			No. of Trials Exhibiting		
Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise	Explosion Flame and Noise	Decomposition Smoke No Noise	No Reaction No Smoke No Noise

Approved:

Test Director

L. C. R.

Test Department Head

L. C. R.

Assigned Classification	
ICC Forbidden	
ICC Restricted*	
ICC Class A	
ICC Class B	

DOD Approval Witnessing
 Signature R. J. Seager
 Title QAR
 Organization DCAS, Pittsburgh

*Shipping Instructions are to be requested from ICC (para 3-13a(2)).

Figure 1. Sample summary data sheet.

AGO 7931A

APPENDIX V

METHOD OF PROCEDURE - CRATERING TESTS

1. Record all preliminary data required on data sheet.
2. Prepare test area as shown in figure 1.
3. Drill $9\frac{1}{2}$ -inch diameter test holes to the depths shown in Table V-I.

Table V-I CRATERING TEST SEQUENCE AND TEST HOLE DEPTHS

Sample	Batch No.	Test Sequence	Hole Depth to Center of Gravity Feet	Actual Test Hole Depth, Feet Inches	
<u>AeReCo 459-23</u>					
1.	17	3	6	6	10.00
2.	1	9	6	6	9.50
3.	2	4	7	7	9.75
4.	2	6	7	7	9.75
<u>AeReCo 475</u>					
1.	18	7	6	6	10.25
2.	2	11	6	6	10.00
3.	3	8	7	7	10.25
4.	4	2	7	7	10.00
<u>Tritonal</u>					
1.	-	1	6	6	7.50
2.	-	12	6	6	7.50
3.	-	5	7	7	7.50
4.	-	10	7	7	7.50

4. Take a one-pint sample of dirt from test hole at 0 feet, 3 feet, and 6 feet depths.
5. Place 3/4-inch steel pipe centering stakes around the hole as shown in figure 2 in order that the center of the bore hole can be located after the explosion.
6. Prepare test charges as follows:
 - a. Label and identify all test samples by sample and test number.
 - b. Tape two No. 6 blasting caps to the sides of two pentolite boosters 180° apart and tape both to sample charge with pentolite booster charge against bottom center of sample. The pentolite charge should be positioned so that the wire leads from the No. 6 caps point away from the bottom of the 30-pound charge.
 - c. Attach sling made from two pieces of Nylon cord wrapped around the bottom of the charge 90° apart and taped to the sides.
7. Lower charge into hole making sure that no debris or dirt prevents the charge from being at the proper depth for test.
8. Make Polaroid and 35 mm photographs of the sample charge and test hole area before lowering charge into hole on any two of the tests.
9. Backfill hole with loose dirt to within 3 1/2 feet of the top of hole for the 6 feet depth and 4 1/2 feet for the 7 feet hole.
10. Clear the area of all vehicles and personnel.
11. Post guards and block all entrances to the test area.
12. Ground initiating circuit at firing shelter and splice wire to blasting caps.
13. When the "ALL CLEAR" signal is given by the Test Supervisor unground circuit and fire charge.
14. Photograph the crater with both Polaroid and 35 mm cameras.
15. After the explosion determine hole profile as shown in figure 2 and record data on data sheet.

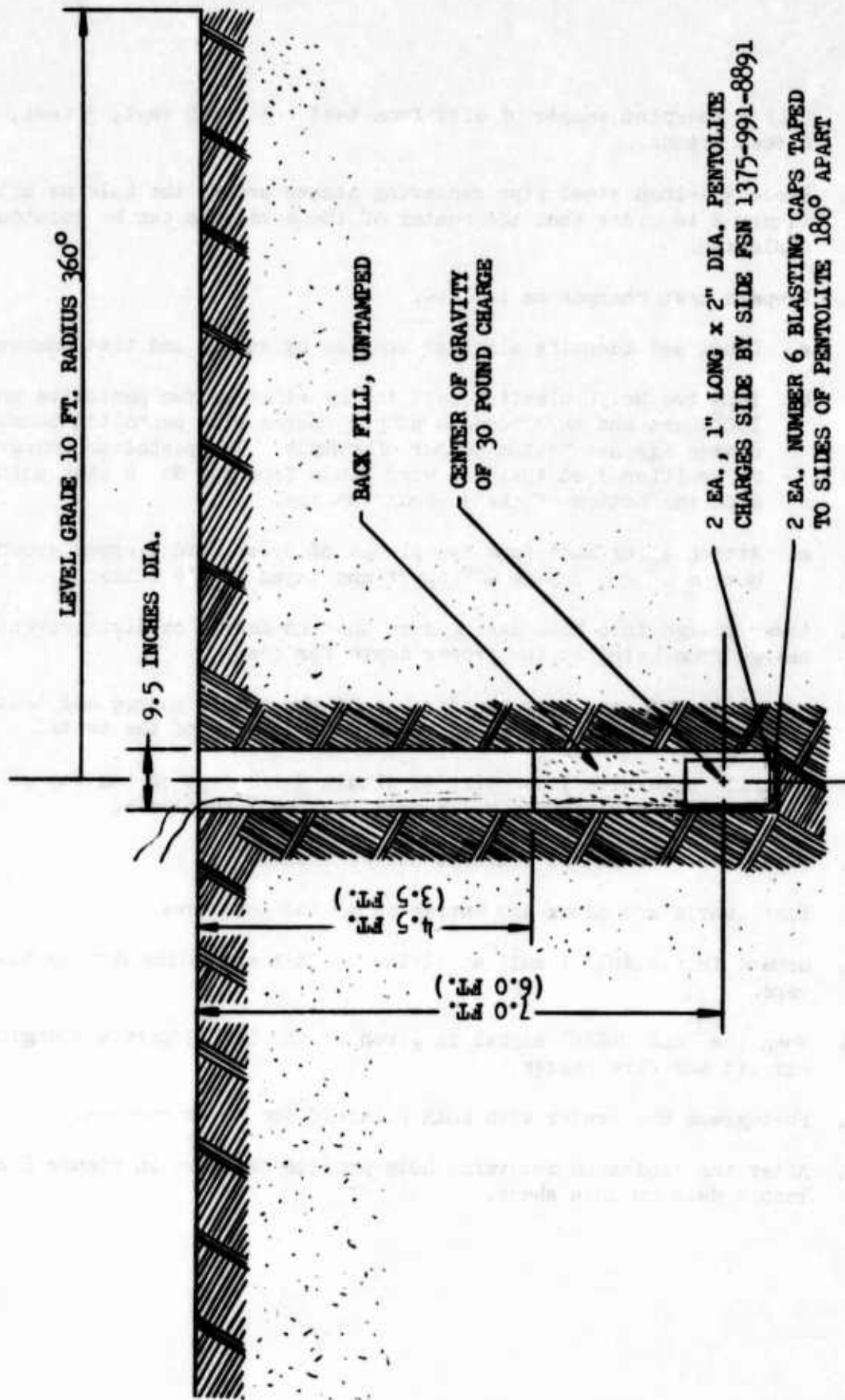


Figure V-1 - View of thirty pound charge in place for cratering test. Pentolite charge and blasting cap are taped to the 30 pound charge prior to lowering into hole. Scale - 1/2 inch equals 1 foot.

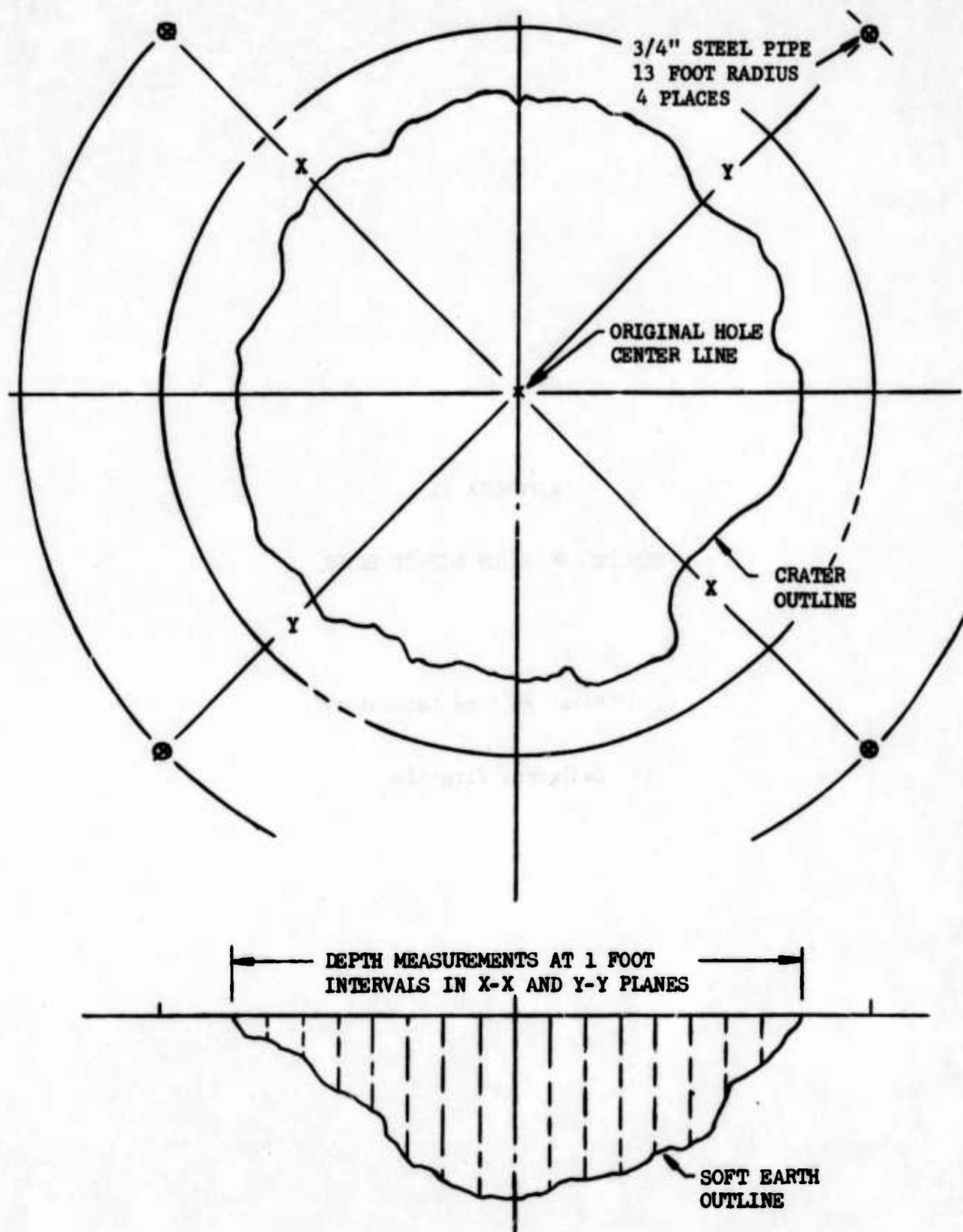
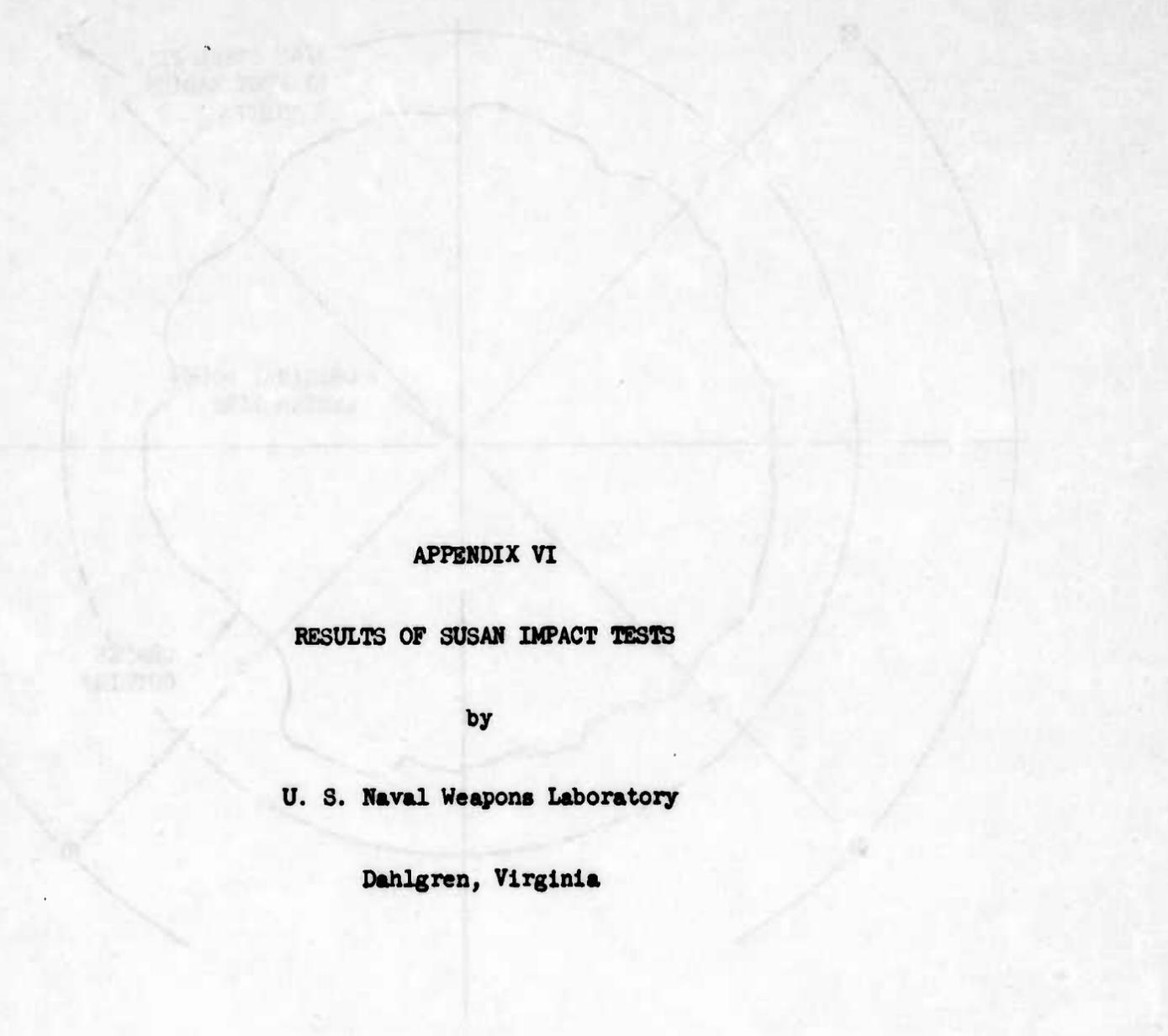


Figure V-2 - Crater shape and cross section showing depth measuring points. Steel pins installed before explosion are used for locating original hole center line after explosion.



APPENDIX VI

RESULTS OF SUSAN IMPACT TESTS

by

U. S. Naval Weapons Laboratory

Dahlgren, Virginia



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U. S. NAVAL WEAPONS LABORATORY
DAHLGREN, VA. 22448

IN REPLY REFER TO

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SEP 27 1968

(Unclassified when enclosures are removed)

From: Commander, U. S. Naval Weapons Laboratory
Dahlgren, Virginia 22448
To: Commanding Officer
Eglin Air Force Base, Florida 32543
Attn: ATWT/LT Trossback/882-2963

Subj: Susan impact sensitivity test of high explosives

Ref: (a) Eglin Air Force Base ltr ATWT/LT Trossback/882-2963 of 7 May 1968
(b) NWL Dahlgren Conf Report No. 1805 of 30 Apr 1962

Encl: (1) Explosive compositions
(2) Summary of Susan impact sensitivity results

1. Susan impact sensitivity tests were conducted on 15 and 16 August 1968 on three explosive formulations as requested by reference (a). The Susan test procedures are described in detail in reference (b).

2. Eighteen Susan projectile assemblies were loaded with explosives at NWS Yorktown; six each with approximately one pound of desensitized tritonal, AeReCo 475, and AeReCo 459-23. The latter two were formulated by Aerospace Research Corporation, (AeReCo) Roanoke, Virginia. The composition of each explosive is given in enclosure (1). The projectiles were gunfired against a steel target plate at impact velocities ranging from 121 to 1250 ft/sec. Instrumentation used to assess the reaction obtained at impact consisted of high speed framing cameras, piezo-electric overpressure gauges, and silicon diode light gauges. Velocities were measured on each firing and were intentionally varied in an attempt to obtain: (1) an approximation of the highest velocity at which no chemical reaction (dud) occurs and (2) the lowest velocity producing a violent reaction (overpressure at 10 ft of 4 psi or greater).

3. A round-by-round summary of the test results is given as Table 1 of enclosure (2). Table 2 lists the estimated threshold velocities for each explosive tested. It should be noted that these estimates are based on very few firings and are subject to change if more rounds are fired. The overpressures given in Table 1 should be considered as approximations and used as comparative values rather than absolute pressures. The numerous reflective surfaces present at the test site influenced the pressures "seen" by the piezo-electric gauges, but were the same throughout all the tests.

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4. The results of the Susan tests, as shown in Tables 1 and 2, indicate that the explosive tritonal (desensitized) is much less sensitive to crushing impact than the other two explosives tested. It is further indicated that the explosive AeReCo 475 is less sensitive to crushing impact than AeReCo 459-23.

W. E. McKenzie

W. E. McKenzie
By direction

Copy to:
Air Force Armament Laboratory
Technology Branch (ATWT)
Eglin AFB, Florida 32542

NAVORD (ORD-03321)
Washington, D. C. 20360

UCLRL
Box 808
Livermore, Calif. 94551
Attn: Chemistry Division (Mr. L. Green)

NWS/Yorktown 23491
Code ORREP

NOS (SADR)
Indian Head, Md. 20640

NOL/WO
Bldg. 613
Silver Spring, Md. 20910

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COMPOSITIONS OF EXPLOSIVES TESTED

<u>Explosive</u>	<u>Formulation (Weight Percent)</u>
Tritonal (desensitized)	TNT 80.00 Aluminum 20.00 D-2 wax Added Lecithin Added Acetylene black Added
AeReCo 475	RDX 75.00 Polyether urethane binder 25.00
AeReCo 459-23	RDX 59.00 Aluminum 23.00 Polyether urethane binder 18.00

Enclosure (1)

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SUMMARY OF SUSAN IMPACT SENSITIVITY TESTS
ROUND BY ROUND RESULTS

Table 1

<u>Projectile Serial No.</u>	<u>Explosive Loading</u>	<u>Impact Velocity (ft/sec)</u>	<u>Average Overpressure at 10 ft (psi)</u>	<u>Reaction Description</u>
BW-70	Tritonal	121	0.0	No detectable reaction
BW-69	Tritonal	320	0.0	No detectable reaction
BW-74	Tritonal	396	1.0	Slight burning
BW-73	Tritonal	494	1.0	Slight burning
BW-71	Tritonal	749	1.1	Slight burning
BW-72	Tritonal	1250	3.8	Moderate burning
BW-76	AeReCo 459-23	123	0.0	No detectable reaction
BW-80	AeReCo 459-23	203	1.0	Slight burning
BW-75	AeReCo 459-23	302	1.4	Slight burning
BW-79	AeReCo 459-23	520	6.1	Near detonation
BW-77	AeReCo 459-23	761	5.3	Near detonation
BW-78	AeReCo 459-23	832	6.5	Near detonation
BW-82	AeReCo 475	122	0.0	No detectable reaction
BW-86	AeReCo 475	200	0.0	No detectable reaction
BW-81	AeReCo 475	314	1.0	Slight burning
BW-85	AeReCo 475	517	5.2	Near detonation
BW-83	AeReCo 475	737	4.3	Vigorous burning
BW-84	AeReCo 475	980	4.7	Vigorous burning

Enclosure (2)

Page 1 of 2 pages

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Ser 0681563

SUMMARY OF SUSAN IMPACT SENSITIVITY TESTS
THRESHOLD VELOCITIES

Table 2

<u>Explosive Loading</u>	<u>Highest "No Reaction"* Velocity (ft/sec)</u>	<u>Lowest "Violent Reaction"** Velocity (ft/sec)</u>
Tritonal	360	1250
AeReCo 459-23	160	400
AeReCo 475	260	450

*This velocity is an estimate of the maximum impact velocity that would produce no chemical reaction.

**This velocity is an estimate of the minimum impact velocity that would produce a reaction greater than moderate burning, accompanied by an over-pressure at 10 ft of 4 psi or greater.

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REFERENCES

1. The Science of High Explosives Melvin A. Cook Reinhold Publishing Company 1958.
2. The Ordnance Safety Manual ORD M7-224.
3. Earth Cratering With Aluminized Explosives, James A. Dennis, U.S. Army Engineer Research and Development Laboratories 18 Dec 1963 AD349660.

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11. SUPPLEMENTARY NOTES Available in DDC		12. SPONSORING MILITARY ACTIVITY Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida	
13. ABSTRACT (C) An evaluation has been made of AeReCo explosives 459-23 and 475. The explosives withstand 350°F for at least one hour and 300°F for eight hours. Their storability qualities are excellent and they are not affected by moisture at any climatic temperature. In cratering tests the AeReCo 459-23 equalled tritonal. Batch type loading techniques were evaluated by loading BLU-31 bombs.			

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High Explosive

Security Classification